a12817

[redacted]

UNCLASSIFIED WT-304

Copy No. 51A

Classification (Cancelled) (Changed to UNCLASSIFIED)
by authority of Ltr. TISE, AEC 2 July 58
by ... Date 29 Sep 58

DTIC ELECTE JUL 24 1995 B

Operation BUSTER - JANGLE

NEVADA PROVING GROUNDS
OCTOBER - NOVEMBER 1951

DTIC ELECTE JUL 24 1995 B

OPERATION BUSTER SOME MEASUREMENTS OF OVERPRESSURE-TIME VS DISTANCE FOR AIRBURST BOMBS

B. F. Murphey, 5111

March 4, 1952

UNCLASSIFIED

DTIC QUALITY INSPECTED 8

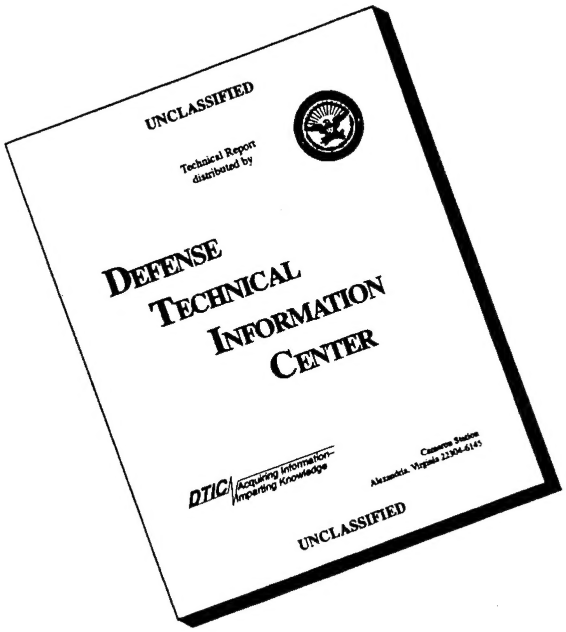
DTIC QUALITY INSPECTED 8

SANDIA CORPORATION
ALBUQUERQUE, NEW MEXICO

[redacted]

UNCLASSIFIED

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

UNCLASSIFIED

WT-304

COPY A

Security Information..

UNCLASSIFIED SECRET

OPERATION BUSTER
SOME MEASUREMENTS OF OVERPRESSURE-TIME VS DISTANCE FOR AIRBURST BOMBS

B. F. Murphey, 5111

March 4, 1952

UNCLASSIFIED RESTRICTED DATA

This document consists of 130 pages
No. 51 of 300 copies, series A

SANDIA CORPORATION

SECURITY INFORMATION—SECRET

UNCLASSIFIED

1-2

[redacted]

UNCLASSIFIED

ACKNOWLEDGMENT

Measurements of pressure vs time on Operation Buster were suggested by a number of persons. That they be carried out by Sandia Laboratory was suggested by E. F. Cox, and these measurements were executed under his general supervision. The layout was designed by G. T. Pelsor, M. L. Merritt, and B. F. Murphey and reviewed with W. E. Ogle, F. B. Porzel, and E. J. Zadina of Los Alamos Scientific Laboratory.

Measurements at the Buster Site were carried out by Division 5233 of Sandia Laboratory under the supervision of H. E. Lenander and R. S. Millican; George Reis was responsible for placement and calibration of the pressure gauges. Recording equipment was installed and operated by O. K. Kowallis with the assistance of Allen Korbe, ETI, USN, and William Payne, RD, USN; V. V. Myers was responsible for cabling and timing.

Data were processed from wriggles on paper to tabular form by the Data Reduction Division of Sandia Laboratory.

UNCLASSIFIED

[redacted]

[redacted]

UNCLASSIFIED

CONTENTS

UNCLASSIFIED

[redacted]

[redacted]

LIST OF ILLUSTRATIONS

[redacted]

[redacted]

LIST OF ILLUSTRATIONS (Cont)

[redacted]

LIST OF ILLUSTRATIONS (Cont)

[redacted]

LIST OF ILLUSTRATIONS (Cont)

[redacted]

[redacted]

OPERATION BUSTER
SOME MEASUREMENTS OF OVERPRESSURE-TIME VS DISTANCE FOR AIRBURST BOMBS

Summary. -- The series of tests conducted at the Nevada Test Site from October 22 to November 5, 1951, was known as Operation Buster. This report deals with measurements of overpressure-time vs distance for airburst weapons. The tests included one tower shot and four air-dropped atomic bombs. The latter four were all nuclear bursts and were designated as Baker, Charlie, Dog, and Easy Shots. Relevant information was obtained for the shots designated Baker, Charlie, and Easy. Only one measurement was obtained for Dog Shot. Data for the first shot, Able, is mentioned briefly. Graphs of pressure vs time are included, accompanied by a discussion of the various observed wave forms. The most salient fact observed is that pressures were lower than had been expected.

* * * * *

The only two atomic bombs which have been dropped in combat (Hiroshima and Nagasaki) were each set to explode at a height believed to maximize the amount of structural damage in the target areas. The selections of the appropriate heights were based on theory and on experiments. Interpretation of data from small high-explosive shots had shown that a bomb burst high over the target would impose pressures, equal to or greater than a preselected minimum pressure, upon a larger area than would a bomb burst near the ground. With a given size bomb the area covered by pressures exceeding a selected minimum pressure would increase with increasing height of burst up to a so-called 'optimum burst height'; for burst heights above this optimum the area covered by the same isobar would decrease rather rapidly with increasing height of burst.

At the time these bombs were detonated in Japan the only actual pressure measurements for an atomic bomb were those obtained at Trinity. Since then several measurements have been obtained for bombs burst within 300 feet of the earth's surface, and one set of measurements has been obtained for a bomb--Bikini Able--burst in the air at an altitude of 518 feet. These data and those from small high-explosive charges, shock-tubes, and theoretical studies, have been used to construct a chart now known as the height-of-burst chart. This chart shows the optimum burst height to maximize a given overpressure in the range 4 to 20 psi. It has been used extensively in connection with the preparation of target folders, perhaps without due regard for the uncertainties expressed at the time of its publication.

During Operation Greenhouse it was established that shock waves associated with atomic bombs are not necessarily precisely the same, at least near the ground, as shock waves observed in connection with high-explosive detonations. The slow rise time of the initial portion of the shock wave, coupled with the lack of pressure-distance data for airburst bombs, made the measurement of shock waves from bombs to be tested on Operation Buster of more than

[redacted]

ordinary interest. It was therefore decided to measure with some care the pressure-time curves for these bursts. These measurements, which turned out to be of somewhat greater interest than had been anticipated, are described in detail here.

The Experiment -- Determination of Points for Height-of-Burst Chart

Obj. Pressure-time vs distance measurements for Operation Buster were designed primari to check the height-of-burst tables[1,2] used extensively in later publications[3,4]. Actually th selected heights of burst for the predicted Buster yields were such that relatively high over-pressures were 'optimized'. It was desirable to carry the measurements in close to ground zero to obtain measurements in the region of regular reflection.

In arranging the layout (Fig. 1) for the gauge stations, a gauge was actually placed at intended ground zero for the Baker, Charlie, and Dog Shots, for which the blast lines (Fig. 3 were primarily designed. To obtain sufficient data to estimate the in-close pressure distri-bution, the gauge stations were placed at 400-ft intervals out to 2,400 feet plus three additio stations out to 5,400 feet. The 'T' layout was chosen because of the possibility that either t of the T might be used as intended ground zero during the B, C, D series. This choice re-sulted in the gauges looking at different portions of the wave front. To some extent pressure distance data would be influenced by any asymmetric properites of the shock front. The pri-mary surface-gauge installations were in a ground baffle; a macadam circle (or pad) of 10-ft radius surrounded the gauge. The macadam was 6 inches thick, and the gauge was mounted vertically in the center. A typical pad is shown in the final stages of preparation in Fig. 2.

Since the transition from regular to Mach reflection has heretofore entered so vitally into the whole notion of optimum heights of burst, an array of gauges was placed 15 feet abov ground to identify this transition. These so-called 'pipe' stations were placed at 400-ft inter vals from 400 to 2,400 feet. The primary aim of the measurement was to find at which sta-tions both incident and reflected waves could be observed and at which stations only the re-flected (Mach) wave would be seen. An altitude of 15 feet above ground was deemed sufficien to give the required time resolution, provided the rise time of the shock wave was negligible compared with 10 to 25 msec. These pipes were oriented toward intended ground zero, and the gauge-bearing members were placed horizontally (Fig. 3). Two gauges were placed on each pipe, one on either side of the pipe in the horizontal plane. (A typical gauge position ca be seen in Fig. 4.) In the region of regular reflection the incident wave struck the pipe at an unsatisfactory angle from the point-of-view of flow. However, after arrival of the reflected wave, and always in the Mach region, the flow should have been satisfactory. It was felt that unsatisfactory flow might upset the pressure-time curve but that the pressure gauge would be a satisfactory means of identifying transition.

The pressure-time curve apparently was measured with moderate accuracy in most in-stances. Although there were some violent oscillations which may represent unsteady flow, there was moderately good agreement between the gauges at 15 feet and those at the surface. There was also good agreement with the 50-ft pipes (Fig. 5), which were intended to measur pressure and arrival times vs altitude.[5]

In choosing sensitivities of the gauges at each station use was made of predicted yields, intended heights of burst, and height-of-burst tables[1,2]. Sensitivities were chosen to allow for the highest predicted pressure and for a possible target miss of 400 feet. The recording system used (Appendix B) is capable of an over-all accuracy of better than 2 per cent. Takin into account the problem of reading back from the recording, the noise level is in the range o

[redacted]

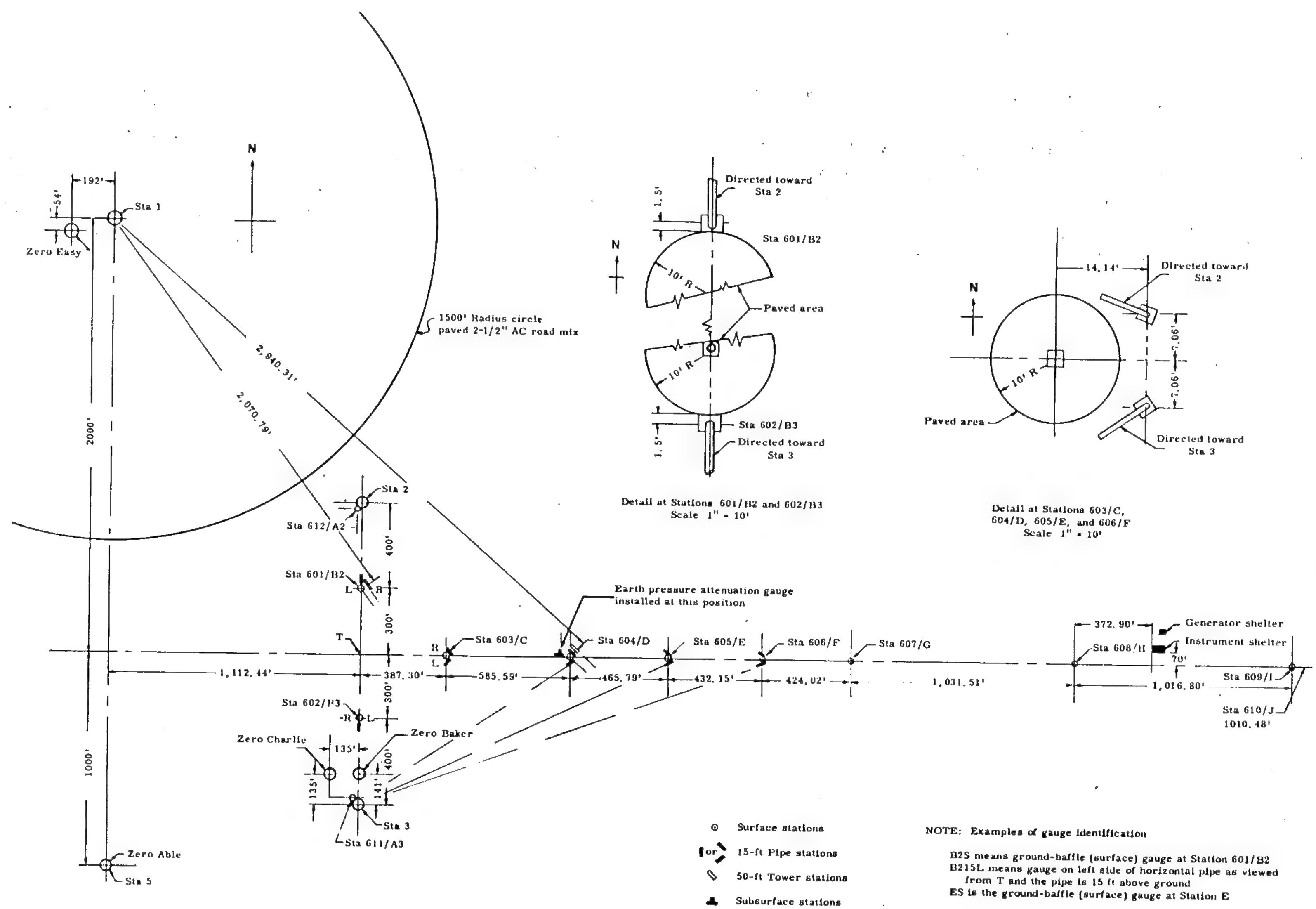


Fig. 1. -- Site plan

[redacted]

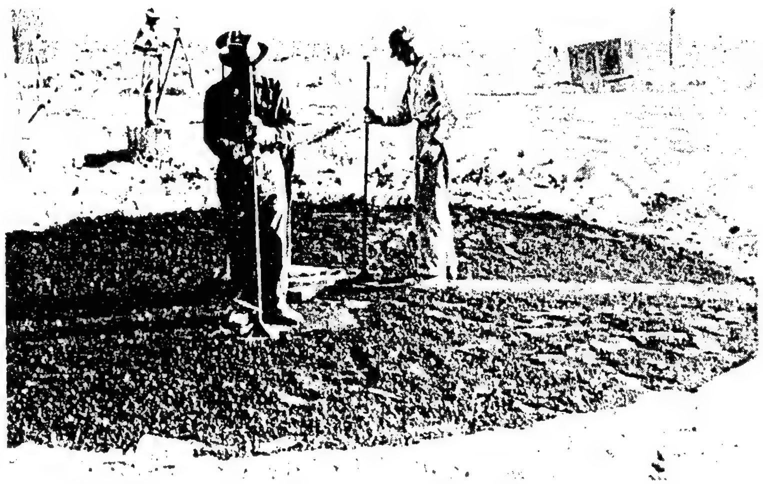


Fig. 2. -- Ground baffle

Final preparation of the 10-ft macadam pad for the surface gauge installation at Station A3S. The vertically mounted gauge was installed at the center of a concrete cube shown in the center of the pad. The pad, which was 6 in. thick, was somewhat buckled following the bursts.

Fig. 3. -- 15-ft pipe stations

Looking east down the blast line; the 15-ft towers are pointing toward shot point 3, which is out of view at the right side of picture. One of the 10-ft ground baffle pads can be seen in front of the closest tower. The ditch, visible in foreground at right center, was filled prior to shot time. The towers shown are those at Stations C (in foreground), D, E, and F.

Stations C (in foreground), D, E, and F.

[redacted]

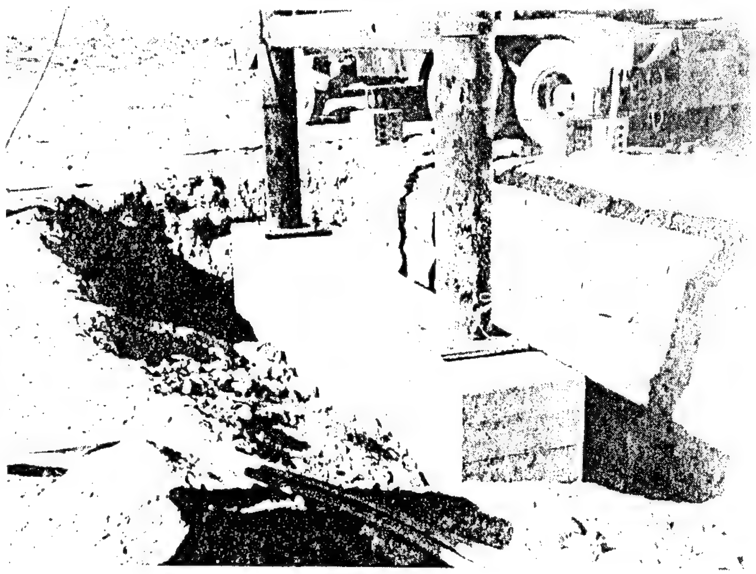


Fig. 4. -- Base of a 50-ft tower

The gauge hole at the 5-ft level can be seen at the top center of the picture. Although the 50-ft tower had a continuous concrete base, as shown, the 15-ft towers had separate concrete footings for each leg.

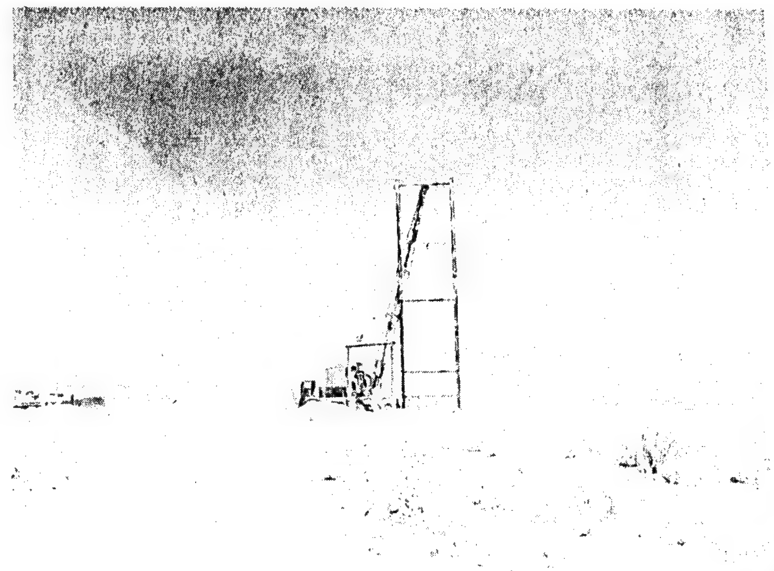


Fig. 5. -- View of 50-ft tower

This tower, oriented toward Shot Point 1 (out of field of view toward left), had gauges at elevations of 0, 5, 10, 25, and 50 ft.

[redacted]

[redacted]

1-2 per cent of the sensitivity. Actually peak amplitudes of pressures recorded were such (observed pressures were not full scale) that the accuracy is at best 5 per cent, and in the most interesting region (out to 2,400 feet) peak pressures may be regarded as having a poss ble error of 10 to 20 per cent. This latter error is judged from the scatter of points on the pressure-distance graphs. No recording system error leading to such a large estimate has been found. A few channels indicated on the pressure-time graphs (Appendix A) are obvious in greater error.

The over-all system is capable of responding to step transients within one msec. The gauges themselves are capable of faster responses.

Because recorded pressures are so low compared with predicted pressures, an effort was made to find any large errors. For example, there was considerable concern over a transient at zero time which forced all the galvanometers off scale, causing a slight permanent set in a few of them. All galvanometers from the two recorders were checked against the factory sensitivity and were accurate within the specified ±5 per cent. Gauge sensitivitie have not yet been reviewed. (However, there is no reason to expect any changes, judging from experience at Greenhouse and one or two field checks made before Buster Easy.) Thus it is concluded that no gross errors occurred which would affect a large number of gauges.

On Shot Dog only one pressure-time curve was recorded because the timing signal sta ing the recording paper arrived 5 seconds late.

Results -- Low Peak Pressures and Unconventional Shock-Wave Forms

Peak pressures shown on the pressure-distance curves (Figs. 6, 7, and 8) were lowe than anticipated. Predicted pressures were plotted from LA-743R, using the heights of bur and yields in Table I.

TABLE I

Shot	Height (ft)	Yield (kt)	$Ht/W^{1/3}$
Baker	1,118	3.1	765
Charlie	1,111	14.0	461
Dog	1,417	21.5	510
Easy	1,314	30.5	422

Examination of Figs. 6, 7, and 8 reveals that the data fall below the predictions in the range of military interest. At large distances observed and predicted peak pressures are more nearly in agreement. It seems conclusive that at large distances (but outside the range of us ful overpressures) the assumption of using twice the yield times some efficiency factor probably gives correct values of peak pressure. That is, viewed from a point somewhere beyo the gauge line, it might be deduced that the yields were as expected. This deduction, from extrapolating the curves, suggests that the assumption of low efficiency is not adequate to explain observed facts shown in Figs. 6, 7, and 8. It will be noted that interferometer gaug readings[6] from points about two miles from the shots, added to Figs. 7 and 8, provide some basis for the extrapolation.

[redacted]

[redacted]

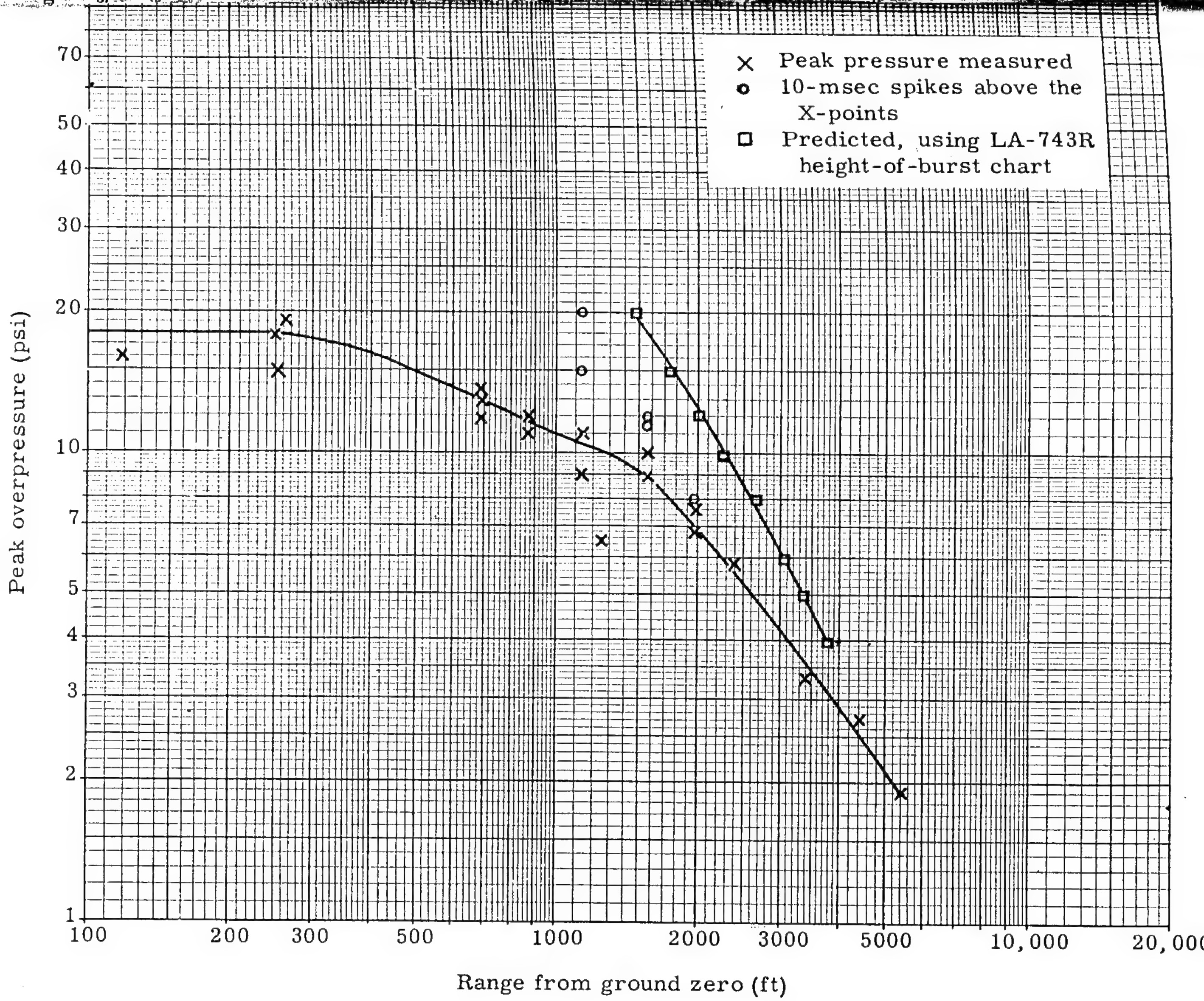


Fig. 6. -- Shot Baker (assumed yield 3.1 kt) (height of burst 1,118 ft)

[redacted]

[redacted]

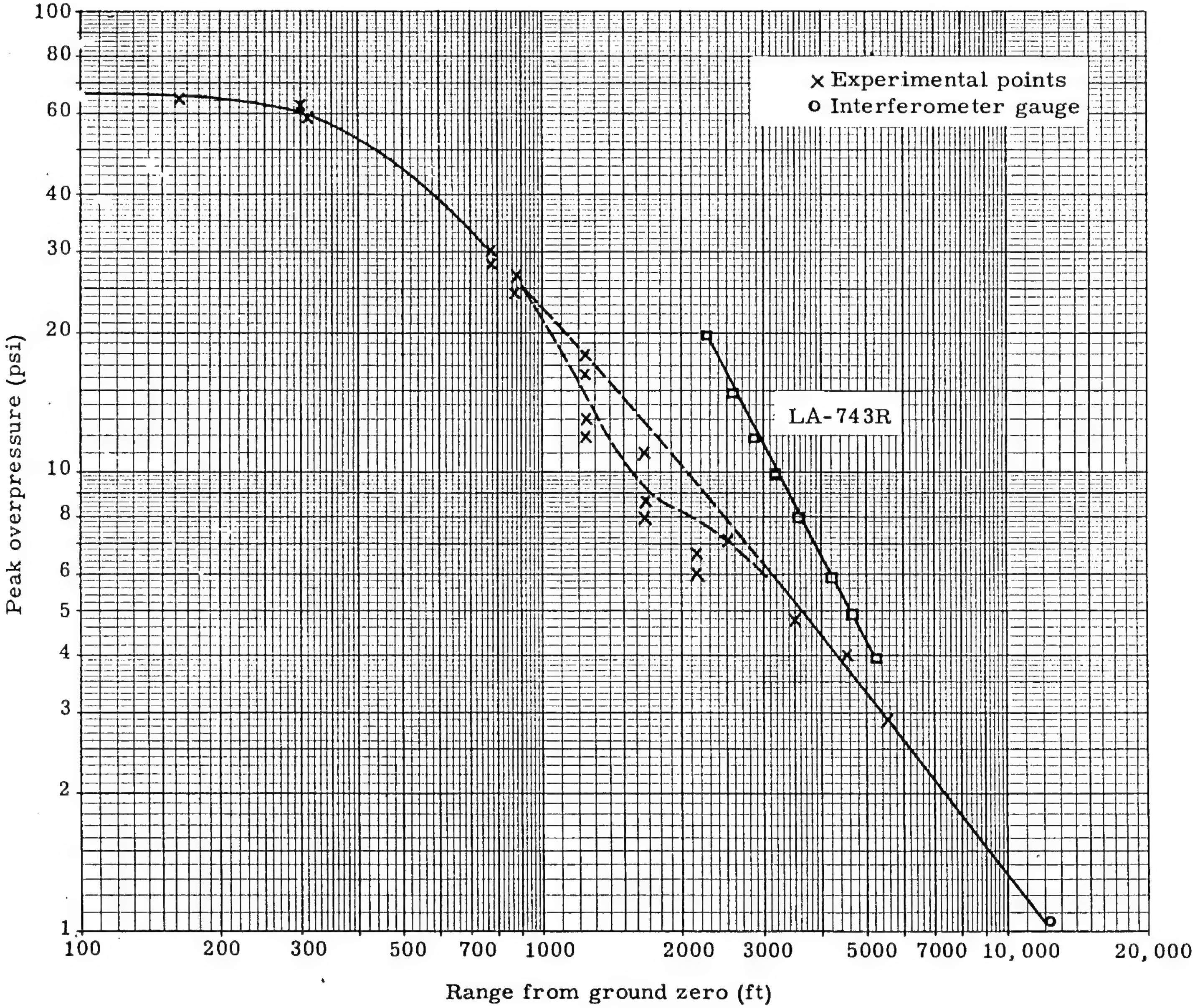


Fig. 7 --- Shot Charlie (assumed yield 14 kt) (height of burst 1,111 ft)

[redacted]

[redacted]

100 200 300 500 700 1000 2000 3000 5000 7000 10,000 20,000

Range from ground zero (ft)

Fig. 7. -- Shot Charlie (assumed yield 14 kt) (height of burst 1, 111 ft)

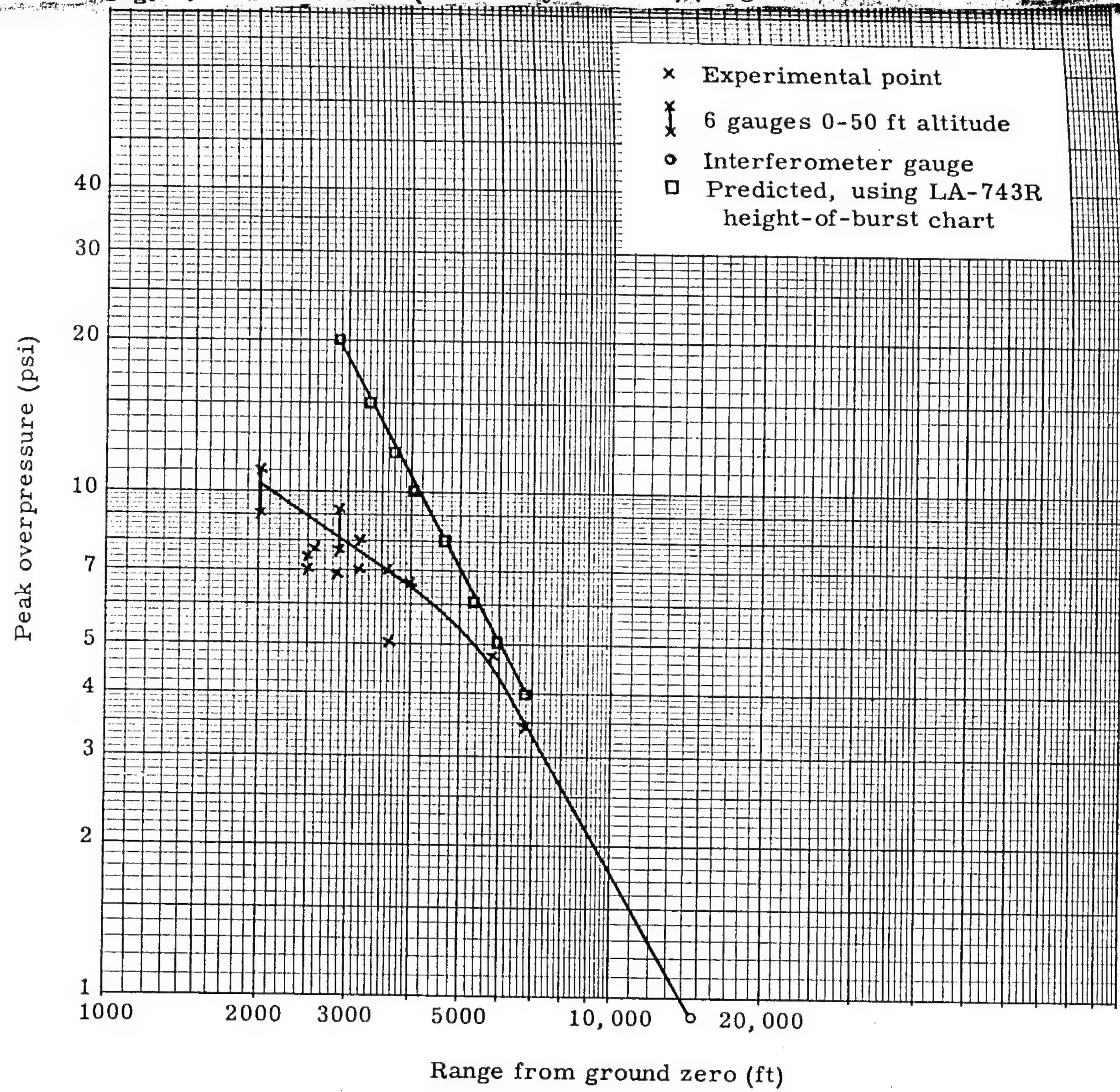


Fig. 8. -- Shot Easy (assumed yield 30.5 kt) (height of burst 1, 314 ft)

[redacted]

Differences between observed and predicted pressure-vs-distance curves can not be e plained simply by assuming a low yield, or a small percentage of the yield going into the bl

Shot Baker. -- The pressure-time graphs for each shot are arranged in Appendix A i sequence according to range from ground zero. Except at gauge stations B2 and B3 the pip gauges are at the same range (or nearly so) as the ground-baffle gauges. (Figure 1 gives d tails such as angles and station designations.)

Except possibly for stations B215L and B215R the shock has a rise time evidently lim only by the response of the measurement system for all gauges mounted 15 ft above ground. Ground baffle gauges show slower rise times (of the order of 10 msec) until the distant gaug are reached; there the recording system again limits rise time. Presumably this slow rise time is an effect of surface roughness, heating of the air near the ground, or possibly ener absorption resulting from work done on dust, or all three.

When their records have sharp rise times, the 15-ft gauges should give information cc cerning transition from regular to Mach reflection. Figures 17-27 show that the incident an reflected waves arrive closer together until they are definitely merged at station D, 1,123 f from ground zero. Records from pipe stations D, E, and F indicate that the Mach stem ha formed prior to arrival of the shock at station D. Moreover, data taken at D, E, and F on Baker are the only examples in which, at the 15-ft altitude, the peak pressures differ mark ly from the lower pressures recorded by the surface gauges. The most interesting feature the larger reading, however, is that near the onset of Mach reflection, the higher pressure short-lived, dropping back to agreement with the surface gauge within about 10 msec. Evi from these few measurements, coupled with shock-tube observations[7], makes it apparent t the very high pressures attributed to Mach reflection near its onset are of short duration. sumably whatever small amount of energy a spike on the 15-ft gauge record contains is com pletely absorbed in the region very close to the ground, since the ground gauges do not show the short-duration peaks. That the Mach effect contributes to higher pressures beyond this region of onset is apparent when pressure values are plotted on a height-of-burst chart.

Pressure-time curves for the pipe stations closer than 1,100 feet indicate that there might be a flow problem. Pressure observed for the incident wave drops rapidly, becoming negative in some instances, and apparently fails to reach the proper peak value for the incid pressure. The flow problem is not serious for the reflected wave, especially once the Mach stem is formed and flow becomes nearly horizontal. The basis on which validity of the pres sure-time curves for the pipe gauges is assumed is that their readings agree moderately we with those from the surface gauges after the reflected wave has combined with the incident wave.

Peak pressures are plotted against range from actual ground zero in Fig. 6 and again slant range in Fig. 9. Figure 9 contains data from surface gauges only, whereas peak pres sures from all gauges are plotted in Fig. 6. Data from the gauge at station ES do not appea in either; they appear unreliable for this shot.

Discussion of the pressure-distance curves will be delayed until data from other shots are presented.

Shot Charlie. -- Though data from Shot Baker may be a little low compared with expectations, the pressure-time curves do have a reasonable resemblance to the one publishe in Effects of Atomic Weapons.[8] However, as can be seen from the pressure-time records for Shot Charlie (Figs. 38-60, Appendix A) recordings at stations B315L and B315R show sharp rise times and reasonable elapsed time (18.4 msec) between incident and reflected waves. Data from stations B215L and R and C15L and R indicate that distinction between th

[redacted]

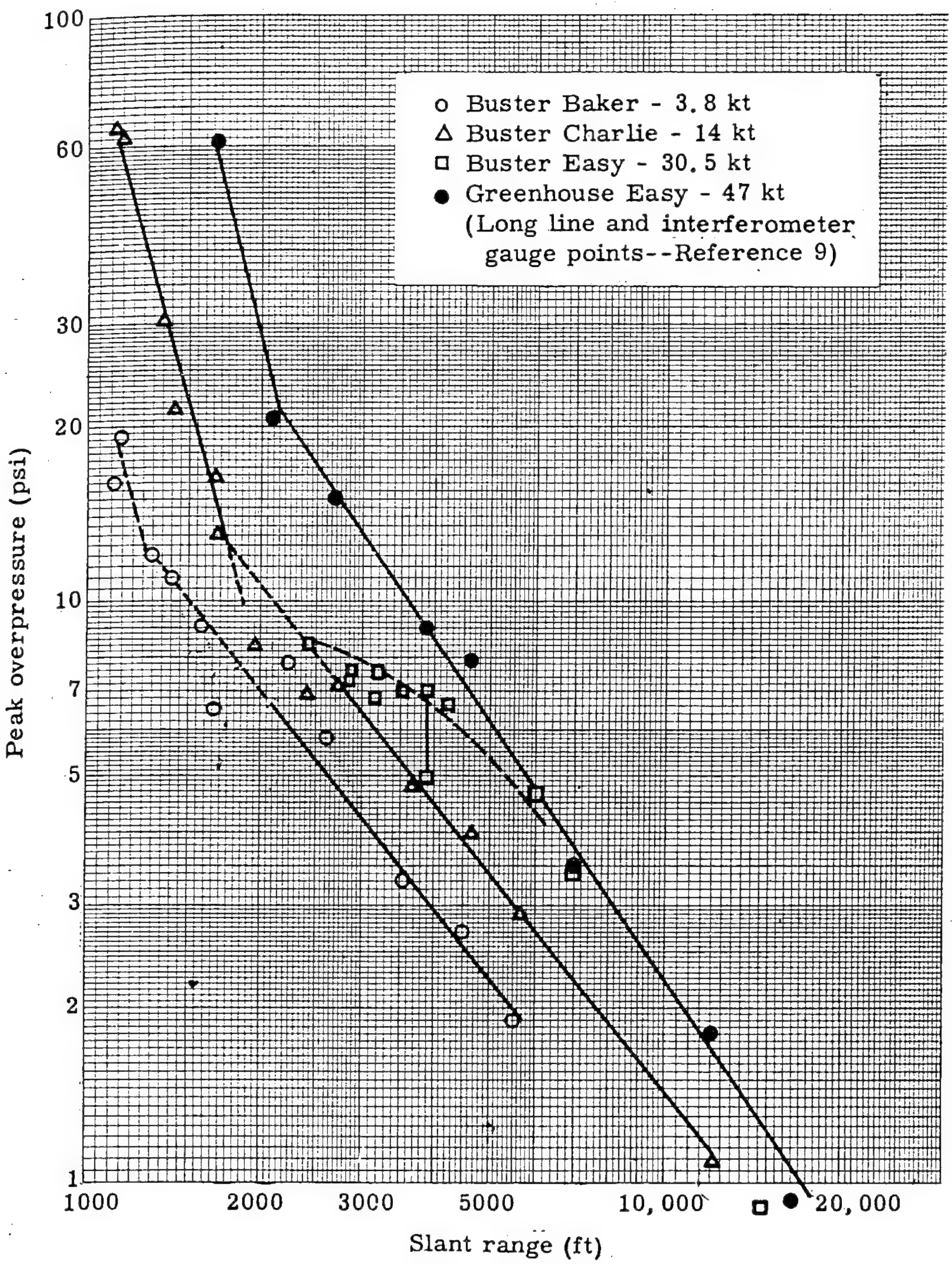


Fig. 9. -- Peak overpressure vs slant range

[redacted]

arrivals of incident and reflected waves is still possible, but superimposed on these reco is a much grosser feature which appears also on that from the ground-baffle gauge. This step, which is graphically illustrated at Station A2S, is still apparent 2,500 feet from gro zero. Station DS had the same slant range as A2S but differed in azimuth by 55°. This s like feature appears to develop beyond 300 feet from ground zero and is partially develop at 800 feet (Stations B2S and CS). Also, beyond C very slow rise times appear. From o experience with Shot Baker it is evident that there is no hope of discerning onset of Mach flection. Something obviously happened to the shock wave on Shot Charlie that did not hap to the shock wave associated with Shot Baker.

Violent oscillations in pressure occurred at several of the gauge stations. The exp ence on Shot Baker suggests that the flow problem is not serious enough to cause these o tions. A satisfactory explanation of the irregular records has not been made. Apparentl gauge 'saw' the 'wiggles', whatever their cause. Since the gauge is sensitive to acceler to some extent (an acceleration of 30 g causes about 1 per cent error for a 30-psi gauge), oscillations might be caused by accelerations rather than pressure variations. The freq of oscillations appears too high to be attributed to the pipe standards, however, and in th most serious examples, at Stations ES, E15L, and E15R, both the pipe and the ground ba gauges show the effect.

Shot Charlie differs from Shot Baker in that slow rise times are exhibited after the few hundred feet of travel. These slow rise times exist up to fifteen feet in height and ac for the absence on Shot Charlie of the high peaks observed at Stations D, E, and F on Sho Baker.

Shot Dog. -- Only one pressure-time curve is available from Shot Dog. A peak ove pressure of 3.5 psi was observed at 5,450 feet.

Shot Easy. -- The gauge line was not designed to cover Shot Easy in the same man as the previous three shots, the closest station being at 2,030 feet. Slow rise times were served out to 5,860 feet except for one of the 50-ft towers. Data for the 50-ft tower at 2, feet have the appearance at all levels of having the peak chopped off for half the positive rise times are slow at all levels. These 50-ft stations are examined more thoroughly els where.[5] Peak pressures observed up to 50 feet were only slightly higher than those obse using ground baffle. This is true at both Stations D and B2.

Whether as a result of asymmetry of the shock front, or errors, large variance ma the remaining data unsatisfactory from the point of view of plotting an accurate pressure- distance curve.

All Shots. -- Peak overpressure vs slant range for all shots is plotted in Fig. 9, w some data from Greenhouse Easy Shot.[9] Cursory examination shows some deviation from Greenhouse data. Buster Shots Charlie and Easy look as though the 7-10-psi region does extend far enough in range. Data from Charlie show that the shock waves suffer some so deterioration after traveling a few hundred feet, and those from Easy show similar behav at Station B2.

It has been hypothesized that a thermal layer is formed near the ground, causing re peak pressures. Presumably this thermal layer would be more effective for Shots Charl and Easy than for Shot Baker since the yields were greater and the burst heights were not respondingly greater. The data indicate that the peak pressure is influenced to heights o to 50 feet above the ground. It is also possible that some energy is taken from the shock by transporting dust. Shot Baker also would be less affected from this cause since the g had not been loosened by previous shots.

 [redacted]

Positive durations are plotted in Fig. 10. These are subject to error to a greater ex- than are the peak pressures because the noise level causes difficulty in choosing the zero rcepts in regions of low-pressure readings. Arrival times vs slant range are plotted in 11. Errors occurred here because a zero time transient burned out the 2-kc standard ng galvanometer in some recorders. It was necessary then to rely upon the timing trace t into the two recorders. Elapsed times are therefore not accurate to 1/2 msec as it was nded they should be, but may be in error by as much as 1 per cent.

A summary of the results of each shot, with graphs of the pressure-time curves, appears ppendix A. Data from Shot Able are not included since they are not applicable to nuclear t results; however, pressures agree approximately with those which would be expected n an HE explosion of 2.9 tons.

Discussion -- Detailed Examination of Findings and Previous Concepts

The intent of the Buster program measurements of air overpressure vs distance was to rmine the extent to which height-of-burst curves might require modification. Most of e questions were raised in LA-743R and required checking at the first opportunity. Some tionable aspects of these curves were:

- The percentage of yield going into air blast
- Reflection coefficients at large distances from the source
- Reflection coefficients in the region of change from regular to Mach reflection (these had been based on intelligent guessing rather than direct measurement, especially for nuclear explosions)
- The degree to which advantages of Mach reflection should be assumed in the pressure vs distance phenomenon, especially as regards military damage

Greenhouse measurements showed slow rise times occurring near ground zero. It was lear that this effect would necessarily be observed for airburst weapons.

Instead of providing detailed answers to the questions posed above, the Buster measure- s have directed attention to some new problems. Buster shots showed:

- Low pressures, especially near ground zero
- Slow rise times on two of the three shots, with peculiar shock wave forms

In Shot Baker, the first shot over the ground zero designated as Station 3, although pres- s are low, the rise times are fast for the gauges mounted 15 feet above ground level. Thus ems reasonable to examine the data for this shot carefully in relation to the original intent. aps a low percentage of yield going into the blast might explain the low pressures since e is no evidence of serious deterioration of the peak pressures. The procedure followed assume that the reflection chart (Fig. 12) is correct and from the known reflected pres- s, angles of incidence, and slant ranges to construct a free air (incident) pressure curve omparison with that which is assumed for the approximate radiochemical yield -- 3.8 kt e latest figure for Shot Baker.

The results of this calculation are presented in Fig. 13, with the free air curve for a t yield (63 per cent of the yield going into the blast). Since the curve does not parallel

[redacted]

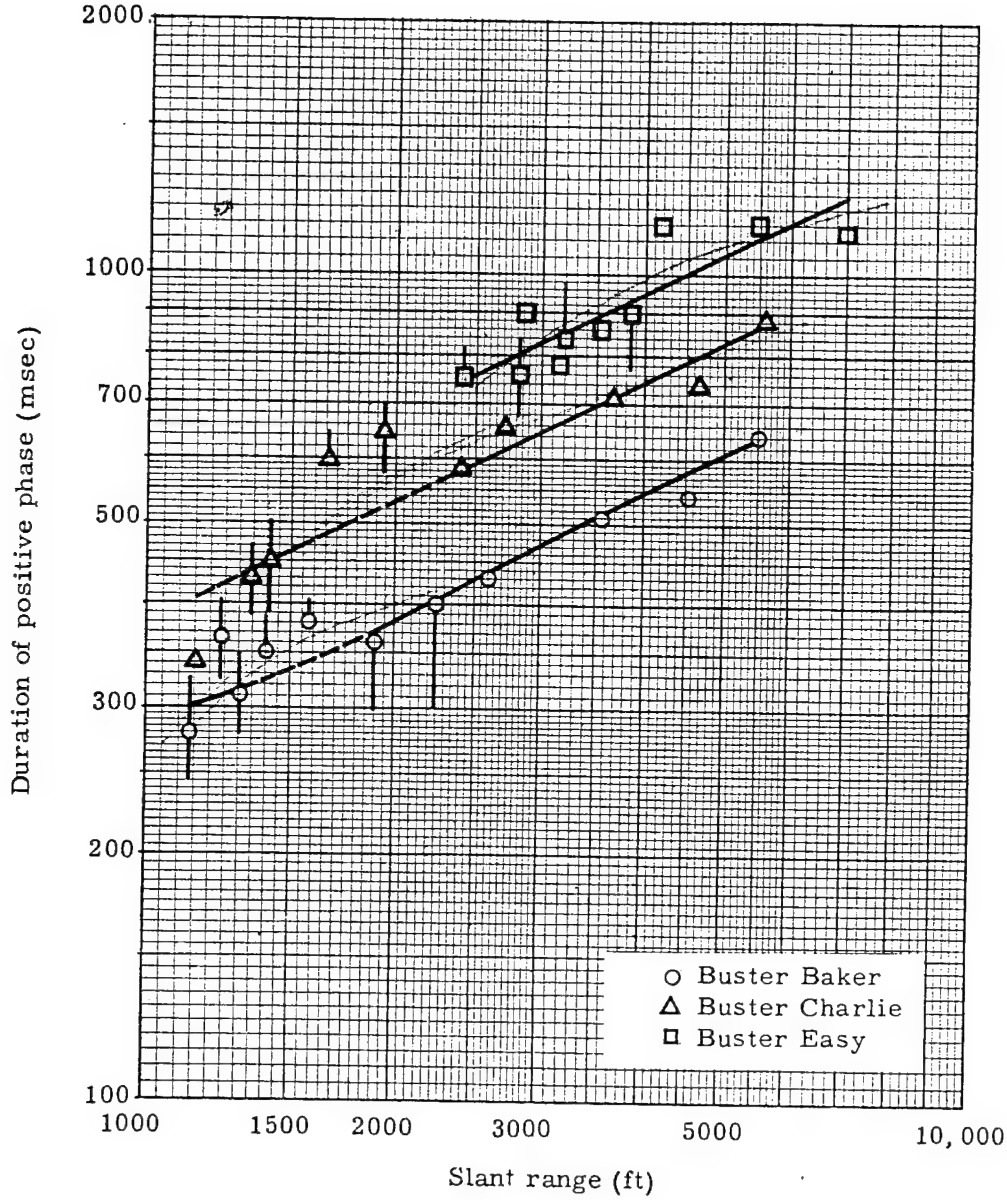


Fig. 10. -- Duration of positive phase vs slant range

[redacted]

[redacted]

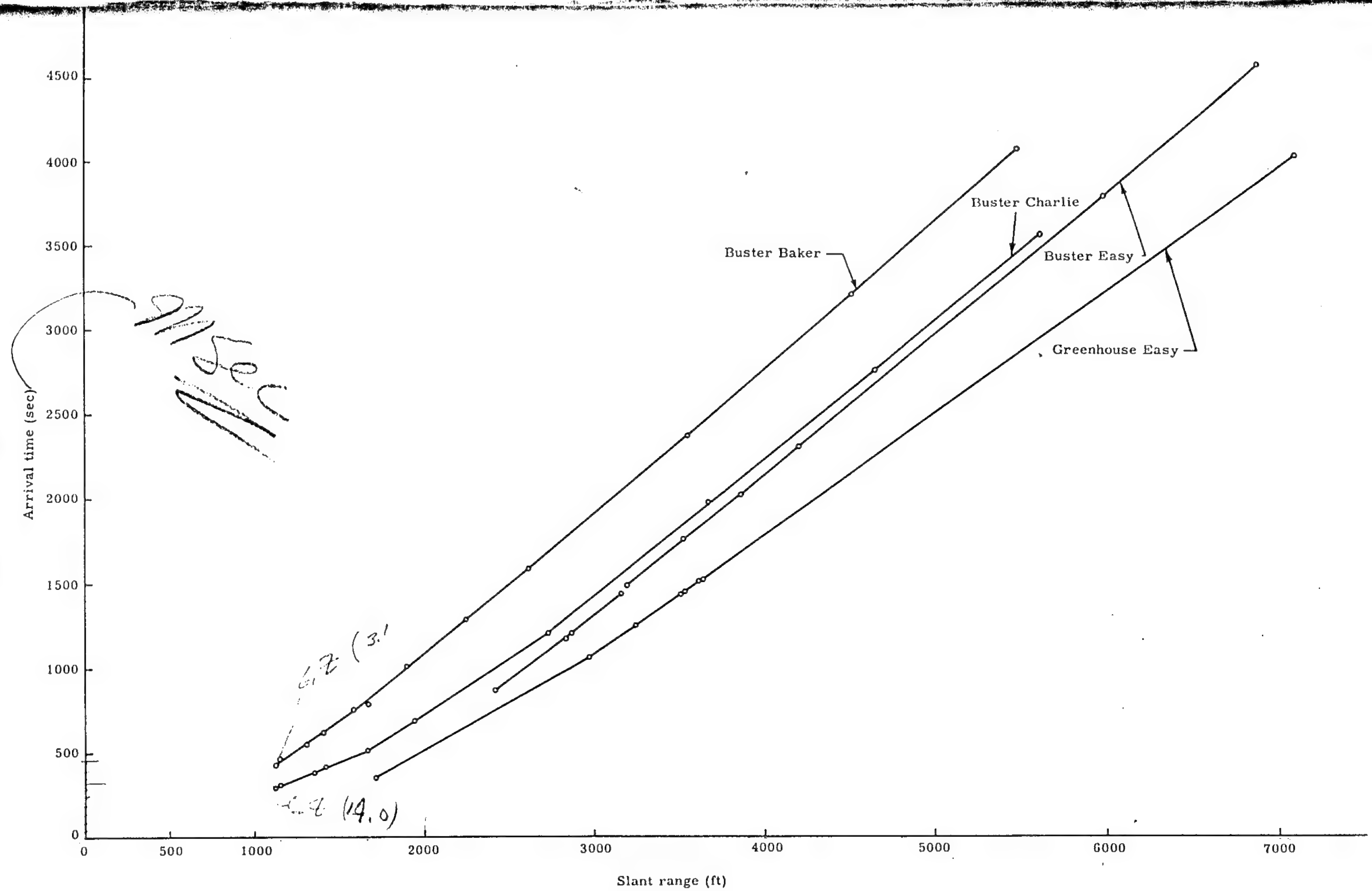


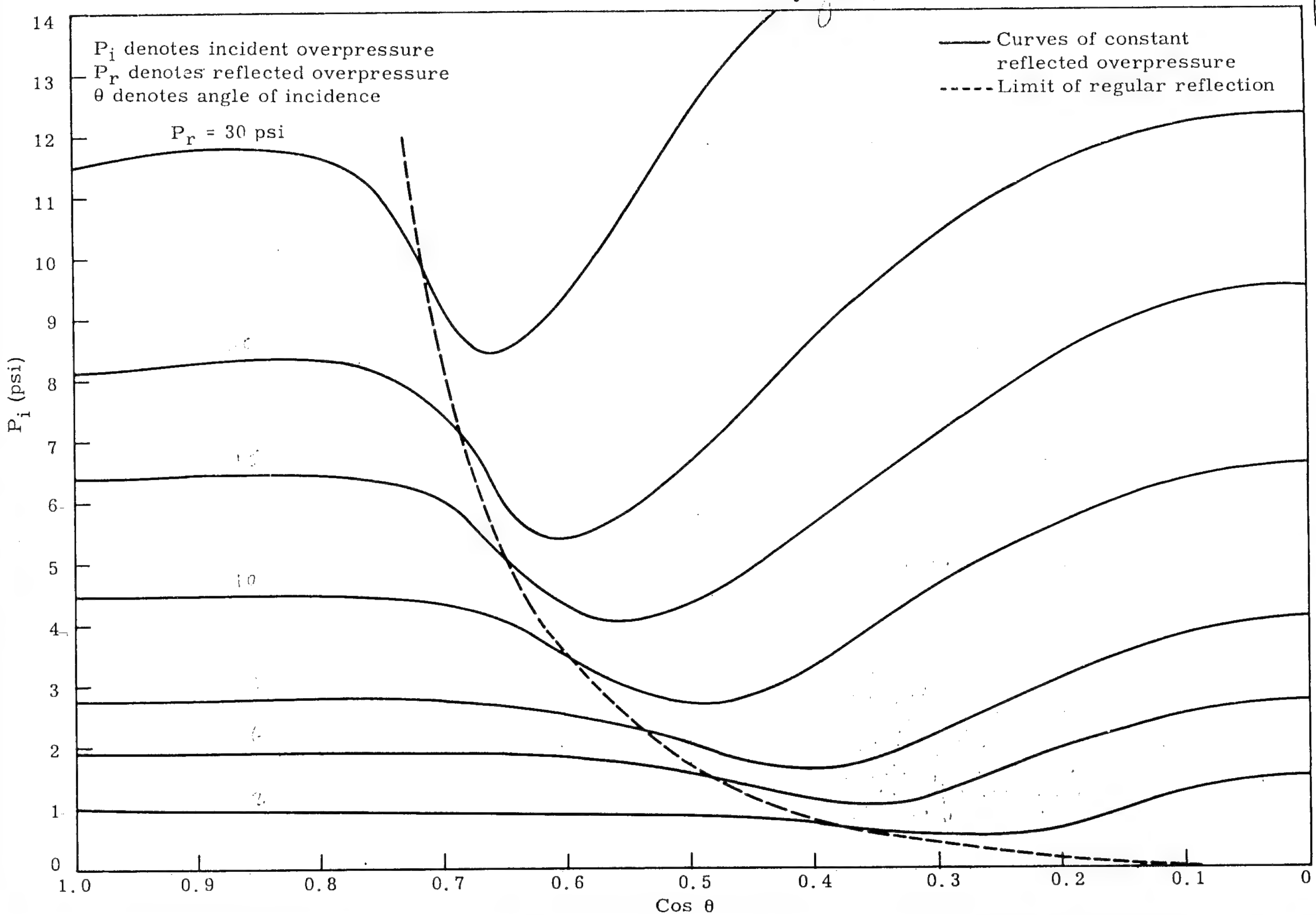
Fig. 11. -- Arrival time vs slant range

[redacted]

[redacted]

Pelsor - Crain Reflection Chart (SC - 1827) TR

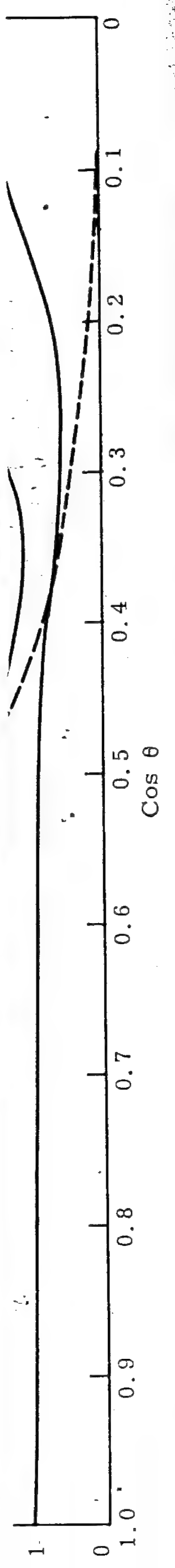
Borke McNair Report



[redacted]

Overpressure (psi)

[redacted]



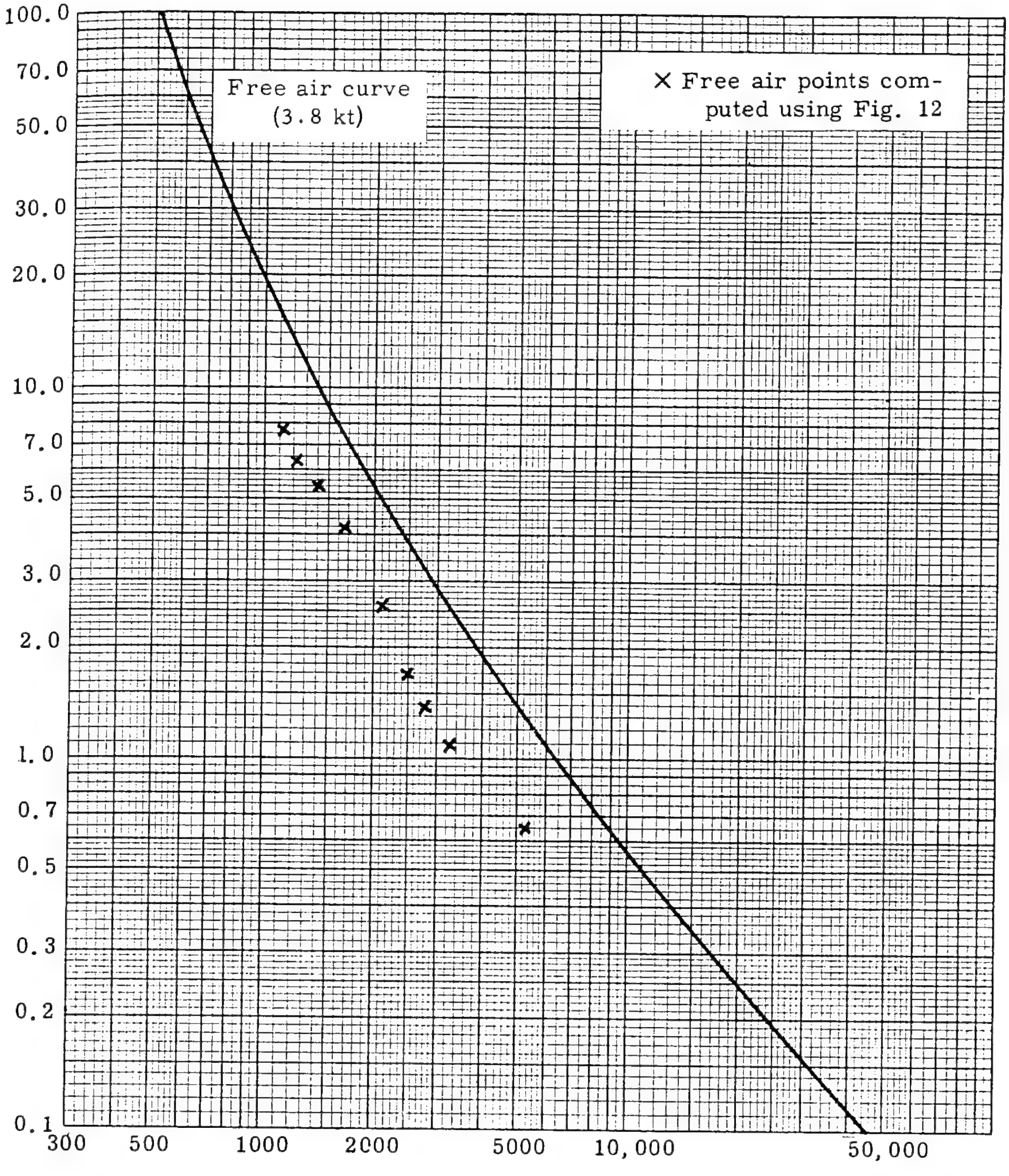


Fig. 13. -- Free air overpressure vs slant range (Buster Baker)

[redacted]

[redacted]

the free air curve, it is concluded that the reflection chart used does not strictly apply. Wh the same procedure is carried out for Shot Charlie, the disparity in the curves is even grea

Since observed pressures were low in the region of measurement, the free air curve a derived above appears to indicate a low percentage of yield going into the blast. This may no necessarily be true, however, because the slope of the curve in Fig. 6 is such that larger yields are implied at large distances than are deduced from the gauged distances.

The conclusion can be drawn that direct use of the reflection chart does not lead to a free air curve parallel to that expected. Therefore under the test conditions this particular reflection chart does not apply.

It is of interest to explore the results of the attempt to detect the growth of the Mach stem, which can be done only on Shot Baker--the only shot in which fast rise times occurred at the 15-ft altitude. Table II shows the time separation between the incident wave and the reflected wave:

TABLE II

Station	Distance from ground zero (ft)	Angle of incidence (°)	Time separation (msec)
B315L&R	242	12	22
C15L&R	681	31.5	10
B215L	876	38	1-2
D15R	1,123	45	0

The two waves have merged at the 15-ft altitude at approximately 900 feet. From 880 to 1,12 feet the reflected pressure is changing from 12 to 10 psi. According to the reflection chart the onset of Mach reflection in this pressure range would occur at an angle of about 50°. Ac ally the onset of Mach reflection, judging from data in Table II, was at approximately 30°. Theoretically this is within the limit of regular reflection. Also the time separation of 10 msec between incident and reflected waves at C15L and C15R is not consistent with that computed from the observed reflected pressure of 13 psi, ie, 18 msec. A possible explanation of these observations is that a heated layer of air above the ground caused the shock wave to travel faster near the ground, thus increasing the angle of incidence and changing the reflection geometry.

The slow rise time observed at the ground baffle stations (compared with that at the pipe gauges) illustrates the expected effect that at ground level the shock front is altered by heating of the air near the ground prior to arrival of the shock and/or a frictional effect. Th fact that the rise time is again rapid at the distant ground baffle stations is evidence that at large distances the heating of the air has a negligible effect.

An interesting feature of pressure-time data from Shot Charlie is that although the ris times are moderately in accord with the ground baffle gauges for Shot Baker out to 300 feet, beyond this distance the shock wave has a step-like rise in pressure. Times of the order of 100 msec elapse before the peak pressure is attained. The shock wave front as observed beyond 300 feet from ground zero shows a deterioration compared with its appearance near ground zero. This deterioration, which is recorded first at stations CS and B2S, is not full overcome until the shock wave has moved out nearly a mile. The effect extends at least to the 15-ft altitude, being observed both on the ground baffle and pipe stations.

[redacted]

[redacted]

Various reasons for this effect may be conjectured, including the much-discussed possibilities of:

Heating of the air near the ground
Energy expended in raising large quantities of dust (previously loosened by Shot Baker) and in overcoming the resulting turbulence
Energy absorbed by the ground

It is suggested that the explanation of the low pressures observed on Shots Baker and Charlie can not be precisely the same, except possibly in the immediate vicinity of ground zero. The peculiar rise to peak pressure at so many stations on Shot Charlie suggests that a new effect took place in addition to what happened on Baker. One obvious difference is that the ground, relatively firm for Shot Baker, was considerably loosened by that shot prior to Shot Charlie, which was fired over the same ground zero. Another difference, of course, is that the ground received more thermal heating from Shot Charlie (heights of burst were nearly the same) and that the incident pressures were somewhat higher.

Shot Easy also provides evidence that in some way the nature of the surface affects the pressure wave as it passes. Shot Easy was fired over a macadam circle 1,500 feet in radius. Figure 8 shows that the pressures recorded on the two outermost gauges do not fall far below the expected levels,[1] whereas the recording on the closest gauges diverge considerably. It could be inferred that because of the better surface near ground zero, the yield looks about right from a distance. In the region where the reflection chart gives large reflection coefficients, the observed pressures are low and rise times are slow. If the six gauges at Station B2, including the two mounted face up at ground level, are accurate, the pressure wave in this region of the front differed considerably from the classical shock-wave form. Unfortunately the gauge line was not designed to record shock waves from Shot Easy, each gauge being on a different radius. (This was also true to a lesser extent of the other shots, in which the gauge line was designed to record shock waves from either Station 2 or Station 3 as intended ground zeros.) Station B2 was also the closest station (2,031 feet). Thus there is no knowledge of the pressure wave in the region of regular reflection, since Mach reflection occurred prior to 1,500 feet.

So much for the characteristics of the pressure-time curves. Ignoring for the moment the nature of the curves and the causes for the observed low pressures, refer again to Figs. 6, 7, and 8. A most entertaining use of the information is to plot some of it on a height-of-burst chart*. To do this the curves must be reduced to 1 kt and correction made to sea level pressure conditions. The pressure correction has the effect of increasing the pressure at a given

---

*Since the observed pressures for Buster were lower than anticipated, considerable study of the data in relation to LA-743R has already been carried out by Los Alamos, Sandia, and AFSWP personnel. The Los Alamos Scientitic Laboratory is publishing a rather complete discussion of the subject in LA-1406, Height of Burst for Atomic Bombs; preliminary revision of the height-of-burst curves based on this theory was published in Supplement 1 to TM 23-200, Capabilities of Atomic Weapons, February 1952, prepared by the Armed Forces Special Weapons Project. A set of experimental height-of-burst curves has been constructed from Greenhouse, Buster, and Jangle data. Possible reasons for disparity with LA-743R are examined, and recommendations for further tests are made.[10] The discussion parallels in part the above-mentioned memorandum, from which the experimental height-of-burst chart (Fig. 14) is taken.

[redacted]

distance by a small percentage. The experimental height-of-burst chart for which the reduced data were employed is shown in Fig. 14. This comparison shows that

At given distances, and especially in the high-pressure region, observed pressures are somewhat lower than the curves show.

The points representing mean effective radii at Nagasaki and Hiroshima are invariant; thus they appear in a lower pressure region if the experimental data are accepted.

There are several reasons for the discrepancy between the observed pressures and the pressures suggested by the curves:

In LA-743R, 1.5 was used as the reflection coefficient at large angles of incidence; therefore the fraction of yield going into an equivalent pentolite yield was 0.75. Using instead a reflection coefficient of 2 has the effect of reducing this fraction and dropping the pressures at given heights along the vertical axis. At 1,120 feet, for example, the 20-psi isobar intercept drops about 200 feet and is replaced at 1,120 feet by the intercept for 13 psi. At large distances, for heights of burst below the knees on the chart the pressures are slightly increased, and over the range 15 to 4 psi the changes are quite small because both calculations relate to the same experimental data (Bikini Able) in this region.

The knee on the curves arises from a strict application of the reflection chart. This chart is in part theoretical and in part based on data from shock tubes and small HE charges. Particularly in the region beyond the onset of Mach reflection, the factor by which the free air pressure is multiplied is somewhat larger than the factor for regular reflection. Also, in this region the experimental data are meager and scattered. There is some evidence, especially from Shot Baker, that these large multiplication factors are not entirely realized, or at least that the high pressures have extremely short durations. All three shots support the conclusion in that the pressures are relatively lower in this region (Figs. 6, 7, and 8) than they are farther out.

The curves at pressures greater than 20 psi have not been computed in detail. For 20 psi the knee is not pronounced. Sample calculations at higher pressures indicate that an isobar of reflected pressure on the reflection chart intersects the line of onset of Mach reflection at higher incident pressures than for normal incidence. The knee of the height-of-burst curve gradually disappears as high-pressure isobars are approached.

The reflection chart is based on a sensitive effect and represents more nearly a theoretical maximum of expectation than a compilation of experience. The theory also deals only with strict shocks. Further study is required to determine the influence of finite rise times on the phenomena of Mach reflection. There is no question but what the reflection chart is valid to some extent, but experimental verification even for HE charges is required.

Perhaps most important of all, but also most difficult to explain in detail, is the fact that the pressures attained in the shock wave are influenced by the character of the surface over which the bomb is burst. A complete study of the possible effects is time-consuming because of the large number of variables. So far as the height-of-burst curves are concerned, the variable nature of surfaces

[redacted]

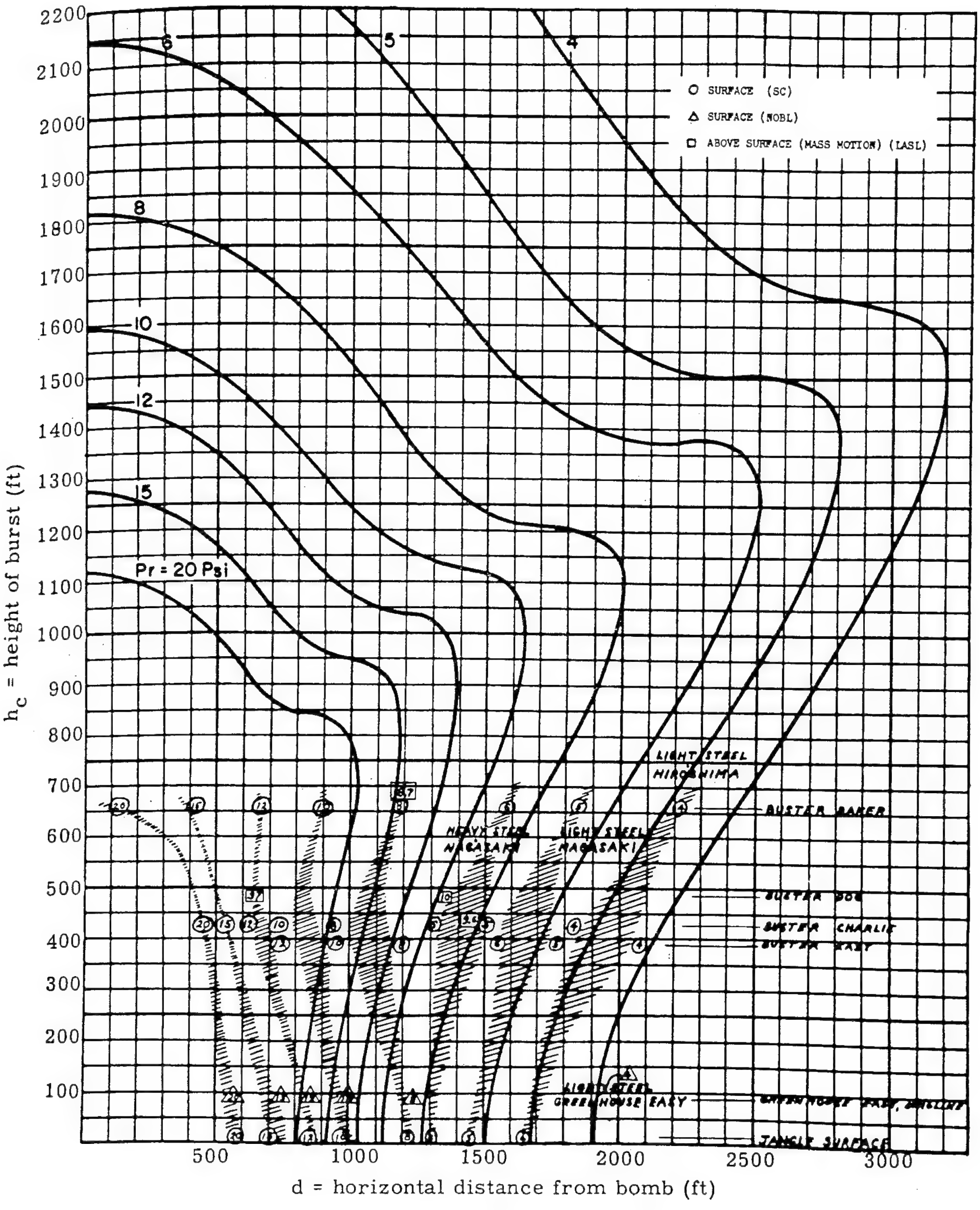


Fig. 14. -- Height-of-burst curve

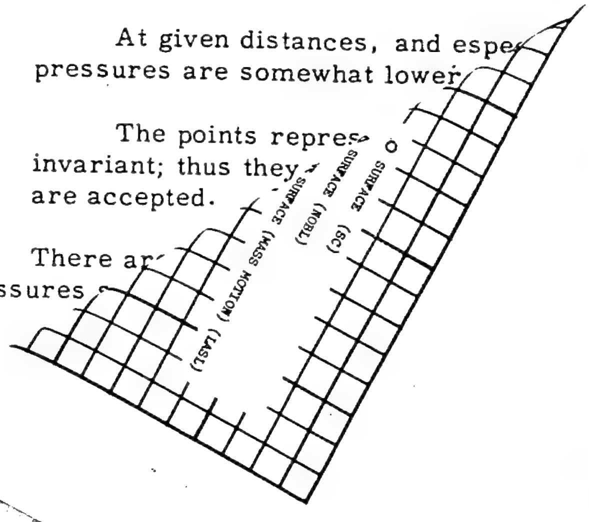
[redacted]

distance by a small percentage. The experimental ... sly any uncertainty
duced data were employed is shown in Fig. 14. ... so a contributing

[redacted]

At given distances, and espe ...
pressures are somewhat lower ... ce can affect the shock wave will
... le thermal or mechanical effect

The points repres ...
invariant; thus they ...
are accepted.



There ar ...
pressures ... e Studies

... rburst bomb it is urged that every effort
... the pressures and mechanisms by which the
... measurements:

... nd altitude
... e-time vs altitude prior to

Den ...
Photog ... cidence and reflection of shock
wave, tu ... etc

The experimental study of the reflection phenomena for HE charges should be accelerated to provide a better understanding of the reflection chart and the effects of different surfaces (even in the absence of thermal radiation).

Greater emphasis should be placed on the fact that the height-of-burst curves and anticipated damage to structures subjected to a given overpressure are not known precisely. An effort should be made to present these facts to the military user in somewhat simpler terms than are used in SC-1827(Tr), which covers the subject in some detail.

Best Available Copy

[redacted]

Appendix A to:
Operation Buster
Some Measurements of Overpressure-Time vs Distance
for Airburst Bombs

Summary of Data and Pressure-Time Curves for
Shots Baker, Charlie, Dog, and Easy

[redacted]

[redacted]

Summary of Blast Data -- Shot Baker

Location	Ground zero distance (ft)	Slant range (ft)	Pressure (psi)	IN Δp	Time of arrival (msec)	Positive duration (msec)
A2S	1,243	1,670	6.5		791	330-400
A3S	117	1,121	16		433	Not reliable
B2S	859	1,405	11		620	350
B215L	876	1,405	12	12.5	633.5	370
B215R	876	1,405	11	2.5	633	375
B3S	259	1,145	19		446	280
B315L	242	1,145	18	10	459	250
B315R	242	1,145	15	3	459	330
CS	681	1,308	12		553.5	290
C15L	681	1,308	13	4	561	300-400
C15R	681	1,308	13.5	4	561	300
DS	1,123	1,585	9		757	380
D15L	1,123	1,585	15		764	5-msec spike
D15L	1,123	1,585	9		-	380
D15R	1,123	1,585	20		765	5-msec spike
D15R	1,123	1,585	11		-	400
E15L	1,543	1,905	11.5		1,015	10-msec spike
E15L	1,543	1,905	9		-	300
E15R	1,543	1,905	12		1,016	8-msec spike
E15R	1,543	1,905	10		-	360
FS	1,953	2,250	7.8		1,288	400
F15R	1,953	2,250	8.00		1,297	5-msec spike
F15R	1,953	2,250	6.8		-	300
GS	2,361	2,615	5.80		1,588	430
HS	3,375	3,555	3.3		2,379	520
IS	4,380	4,520	2.7		3,209	580
JS	5,385	5,510	1.9		4,059	640

From aiming point:

N	141	feet
W	0	feet
H	1,118	feet

[redacted]

[redacted]

Summary of Blast Data -- Shot Charlie

Location	Ground zero distance (ft)	Slant range (ft)	Pressure (psi)	Time of arrival (msec)	Positive duration (msec)
A2S	1,246	1,668	13	520	600
A3S	163	1,122	65	298.4	-
B2S	877	1,415	26.5	418	385
B215L	894	1,415	26.8	469	400
B215R	894	1,415	24.6	469.5	500
B3S	298	1,152	62	307	-
B315L	281	1,152	60	320.1	340
CS	768	1,352	30.5	386	415
C15L	768	1,352	28.5	418	470
C15R	768	1,352	30	417	405
DS	1,245	1,668	16.4	516	630
D15L	1,245	1,668	12±1	524	580
D15R	1,245	1,668	18±2	524	580
ES	1,673	1,945	8.5	690±3	700
E15L	1,673	1,945	8±1	698	600
E15R	1,673	1,945	11	698	600
FS	2,138	2,410	6.5 - 7±1	-	-
F15R	2,138	2,410	6	920	590
GS	2,495	2,735	7.20	1,202±3	660
HS	3,505	3,675	4.8	1,977	710
IS	4,520	4,660	4.0	2,754	736
JS	5,520	5,630	2.9	3,557	883

From aiming point:

N	135 feet
W	135 feet
H	1,111 feet

[redacted]

[redacted]

Summary of Blast Data -- Shot Easy

Location	Ground zero distance (ft)	Slant range (ft)	Pressure (psi)	Time of arrival (msec)	Positive duration (msec)
A2S	1,732	2,174	No Signal	-	-
A3S	2,873	3,159	6.8	1,439	780
B2S	2,031	2,420	8.5	870	770
B2P0	2,031	2,420	11	871	740
B2P5	2,031	2,420	10	871	740
B2P10	2,031	2,420	11	873	780
B2P25	2,031	2,420	10	879	780
B2P50	2,031	2,420	9	888	800
B3S	2,541	2,862	7.6	1,210	900
CS	2,505	2,832	7.3	1,180	700
C15L	2,505	2,832	7.0	1,187	750
C15R	2,505	2,832	7.4	1,183	840
DS	2,910	3,195	7.6	1,490	790
DPO	2,910	3,195	8.5	1,493	800
DP5	2,910	3,195	8.5	-	820
DP10	2,910	3,195	8.7	-	860
DP25	2,910	3,195	9	1,500	1,000
DP50	2,910	3,195	9	1,503.7-1,515.6	850
ES	3,270	3,527	7	1,761	840
E15L	3,270	3,527	7	1,764	850
E15R	3,270	3,527	8	1,765	880
FS	3,630	3,862	5	2,025.5	900
F15R	3,630	3,862	7	2,030	750
GS	3,995	4,210	6.60	2,301.6	1,300
HS	4,915	5,085	No Signal	-	-
IS	5,860	6,000	4.7	3,776	1,300
JS	6,750	6,950	3.4	4,569	1,250

From aiming point:

S 54 feet
W 192 feet
H 1,314 feet

[redacted]

[redacted]

Pressure-Time Data
Shot Baker

[redacted]

[redacted]

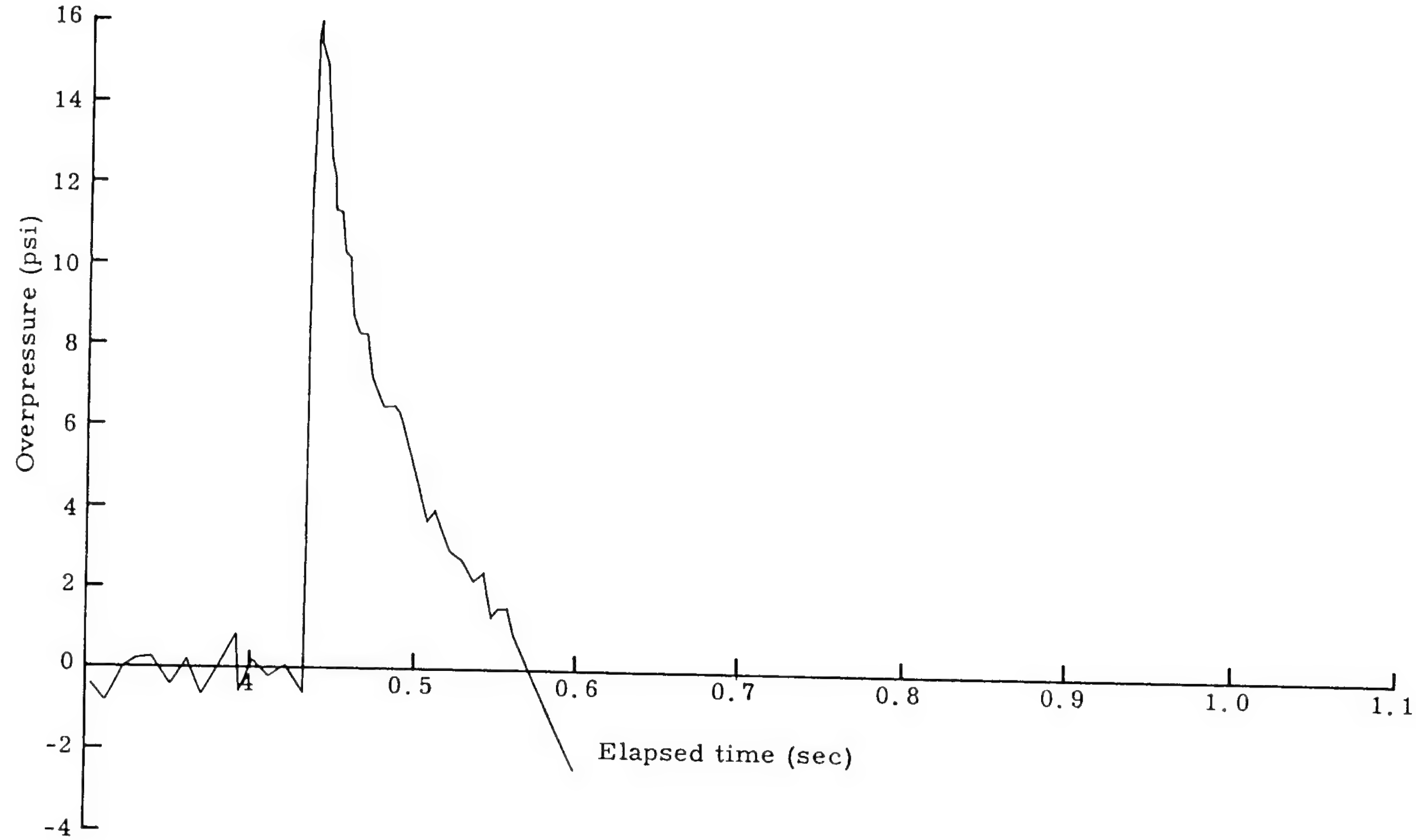


Fig. 15. -- Shot Baker (A3S) (ground baffle) (distance from ground zero: 117 ft)

[redacted]

[redacted]

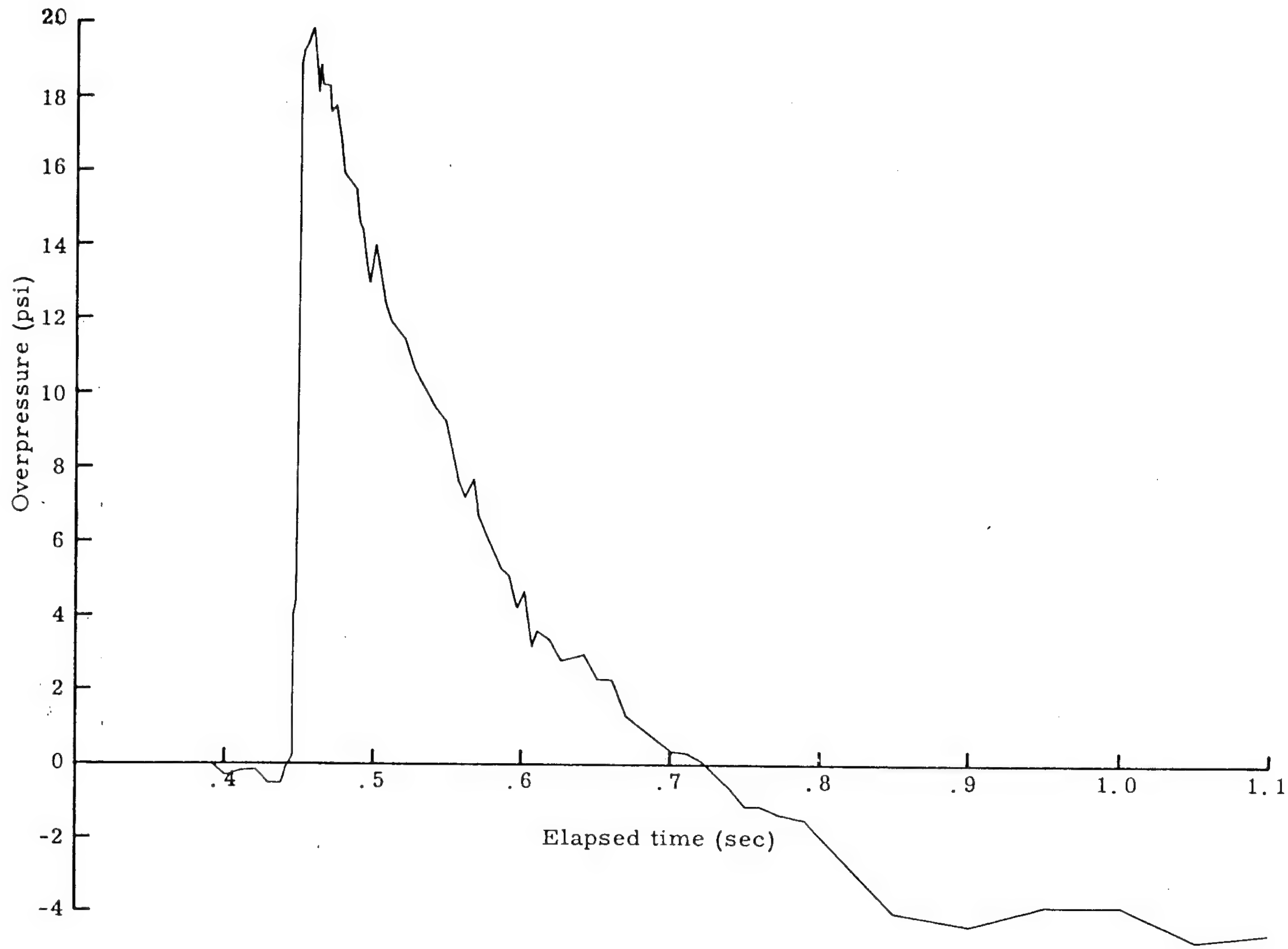


Fig. 16. -- Shot Baker (B3S) (ground baffle) (distance from ground zero: 259 ft)

[redacted]

[redacted]

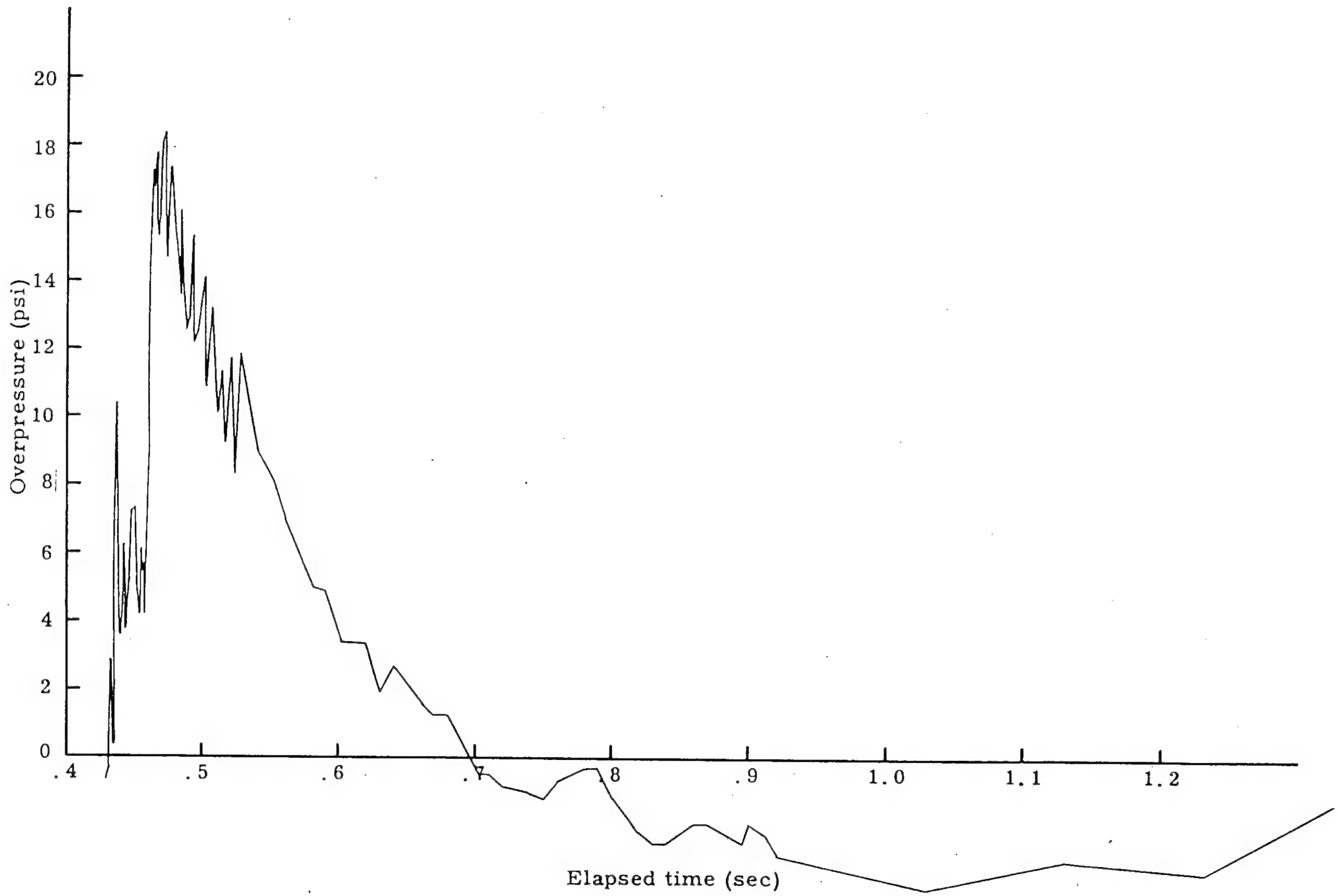


Fig. 17. -- Shot Baker (B315L) (gauge 15 ft above ground) (distance from ground zero: 242 ft)

[redacted]

[redacted]

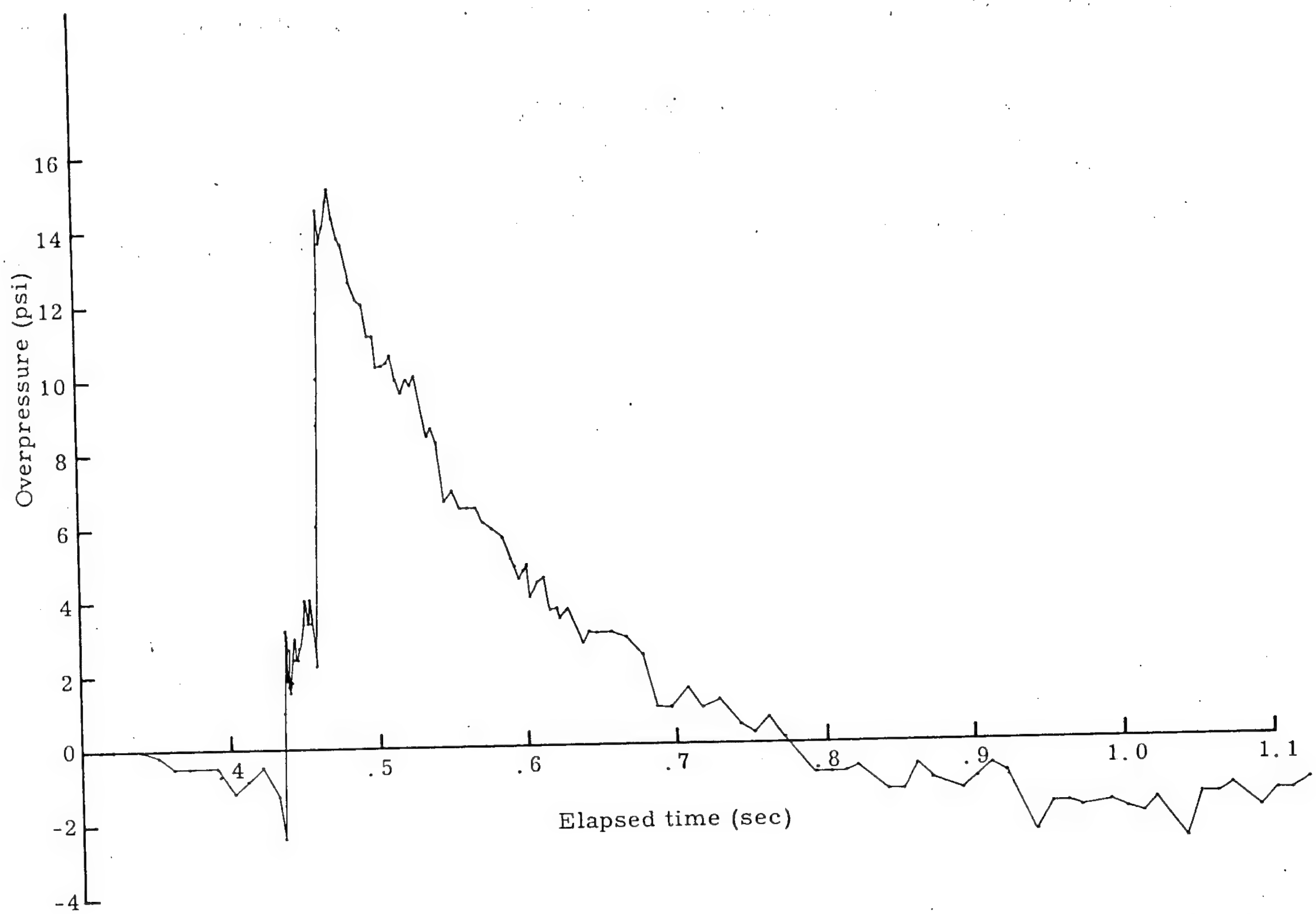


Fig. 18. -- Shot Baker (B315R) (gauge 15 ft above ground) (distance from ground zero: 242 ft)

[redacted]

[redacted]

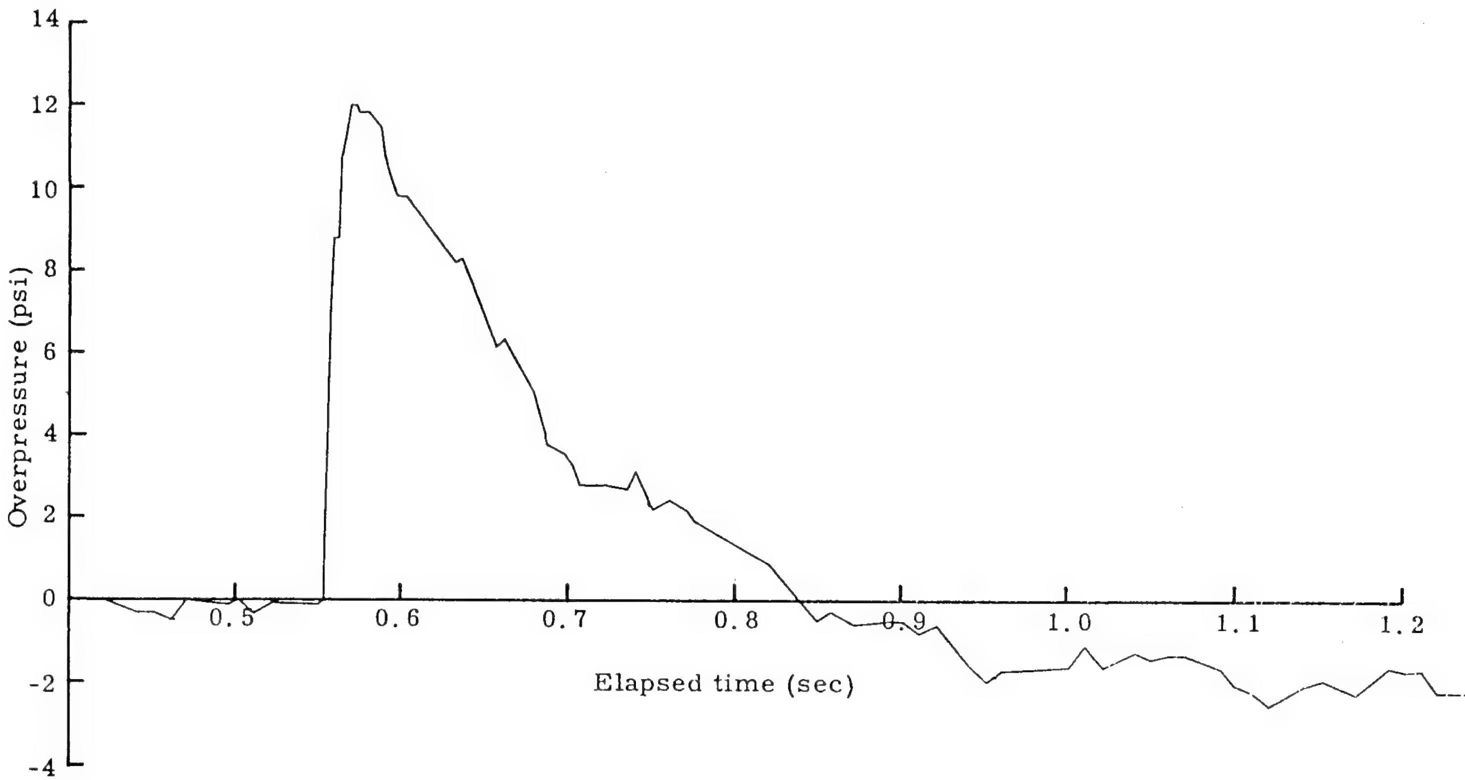


Fig. 19. -- Shot Baker (CS) (ground baffle) (distance from ground zero: 681 ft)

[redacted]

[redacted]

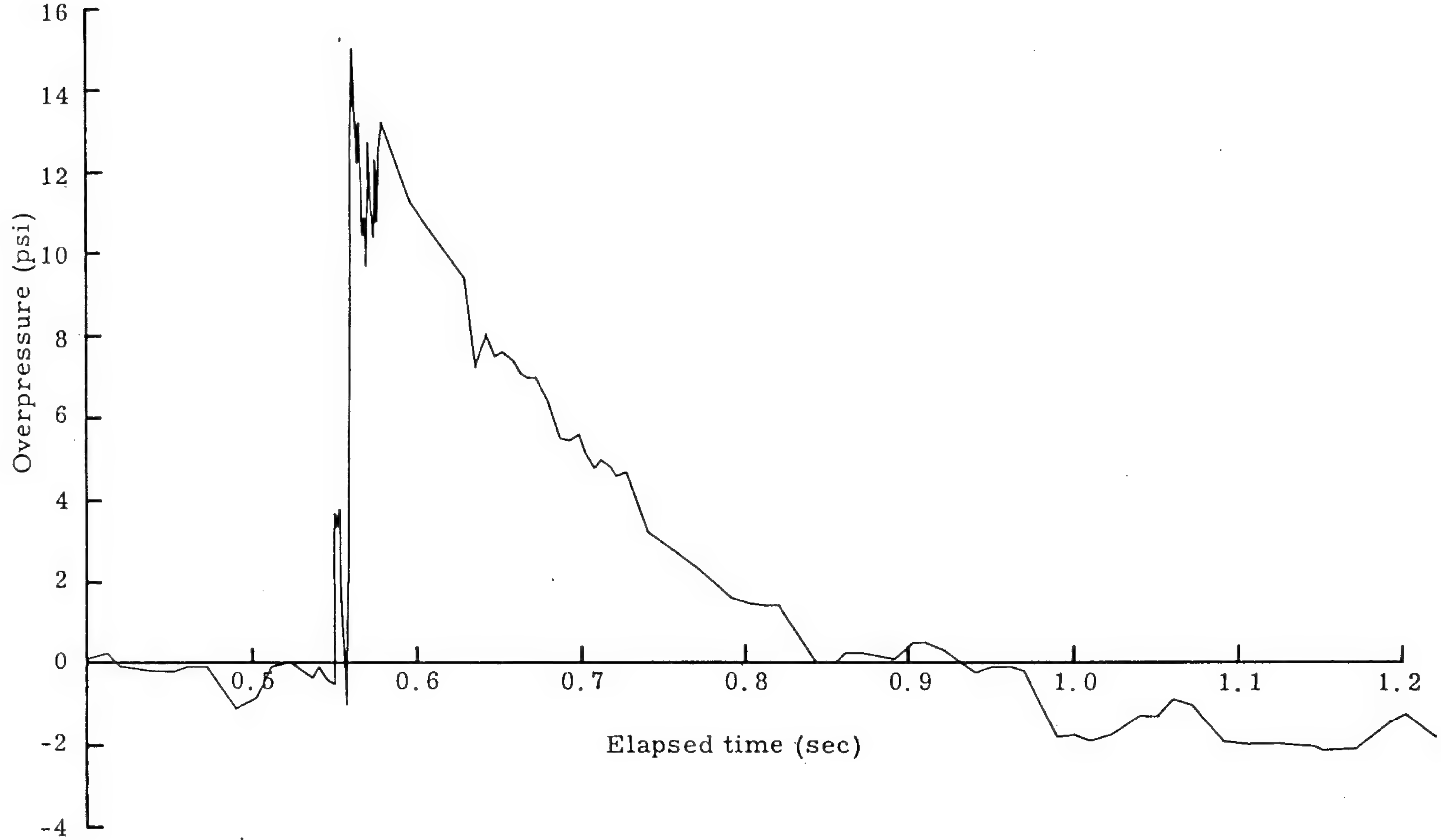


Fig. 20. -- Shot Baker (C15R) (gauge 15 ft above ground) (distance from ground zero: 681 ft)

[redacted]

[redacted]

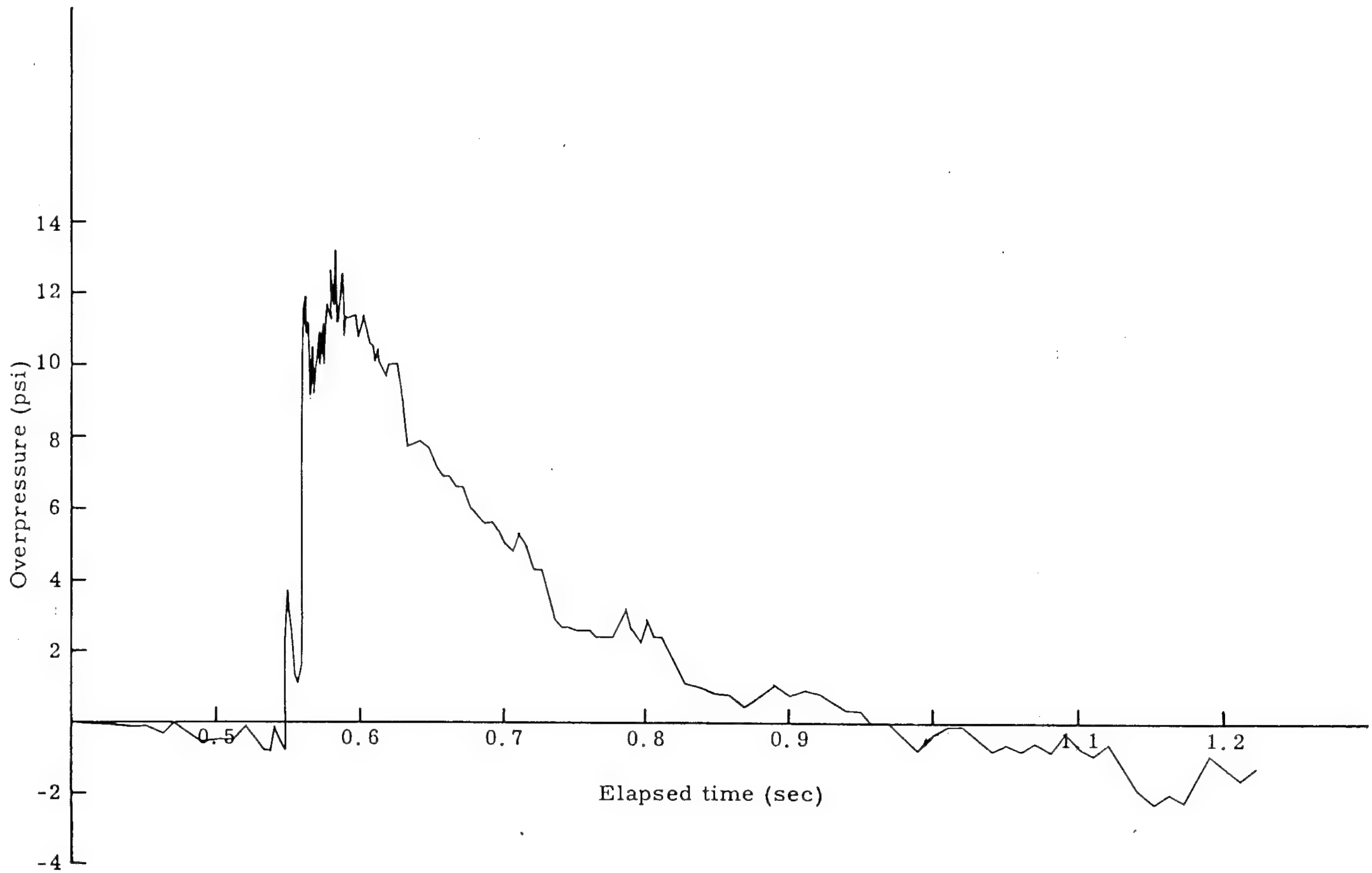


Fig. 21. -- Shot Baker (C15L) (gauge 15 ft above ground) (distance from ground zero: 681 ft)

[redacted]

[redacted]

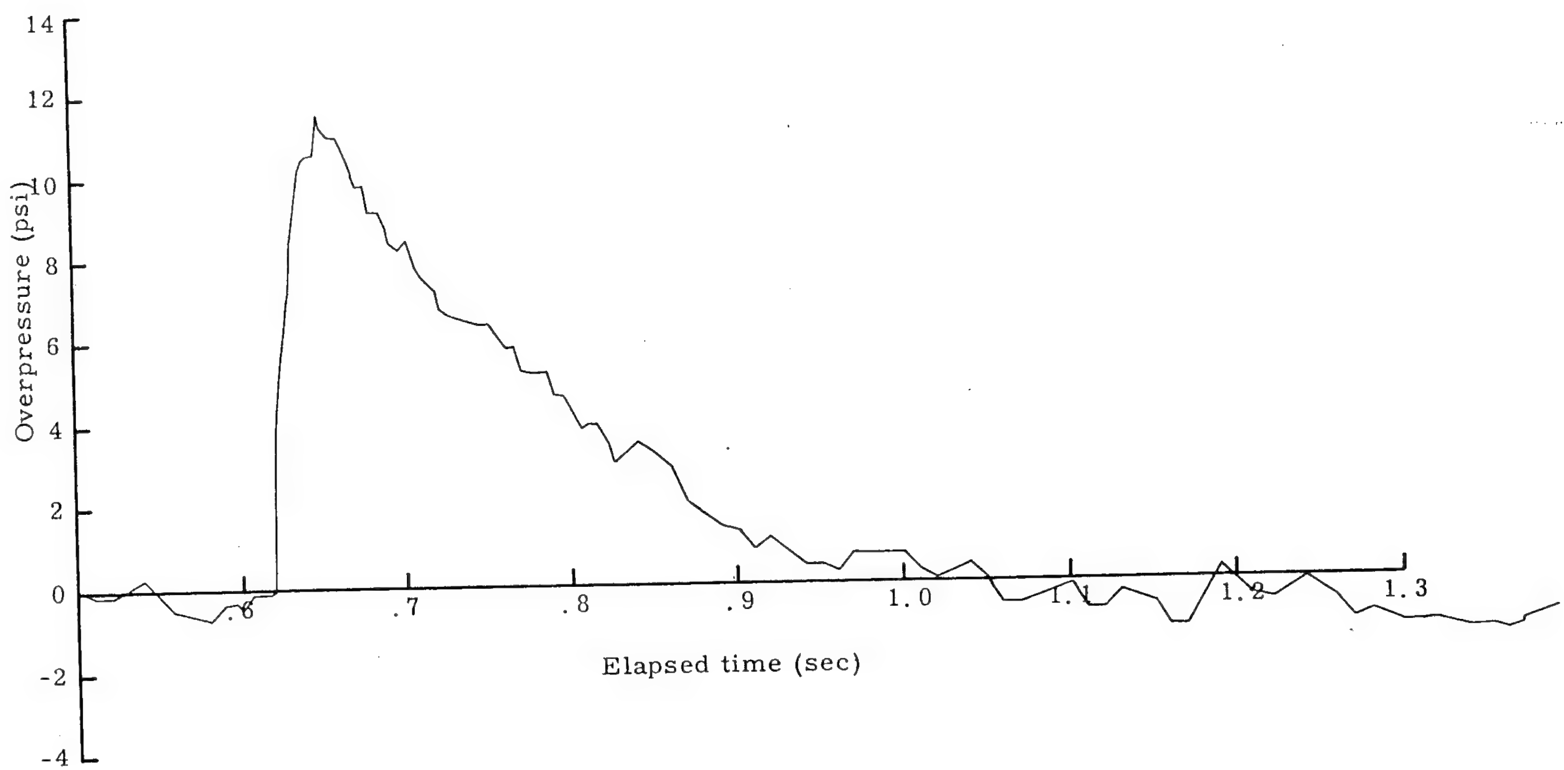


Fig. 22. -- Shot Baker (B2S) (ground baffle) (distance from ground zero: 859 ft)

[redacted]

[redacted]

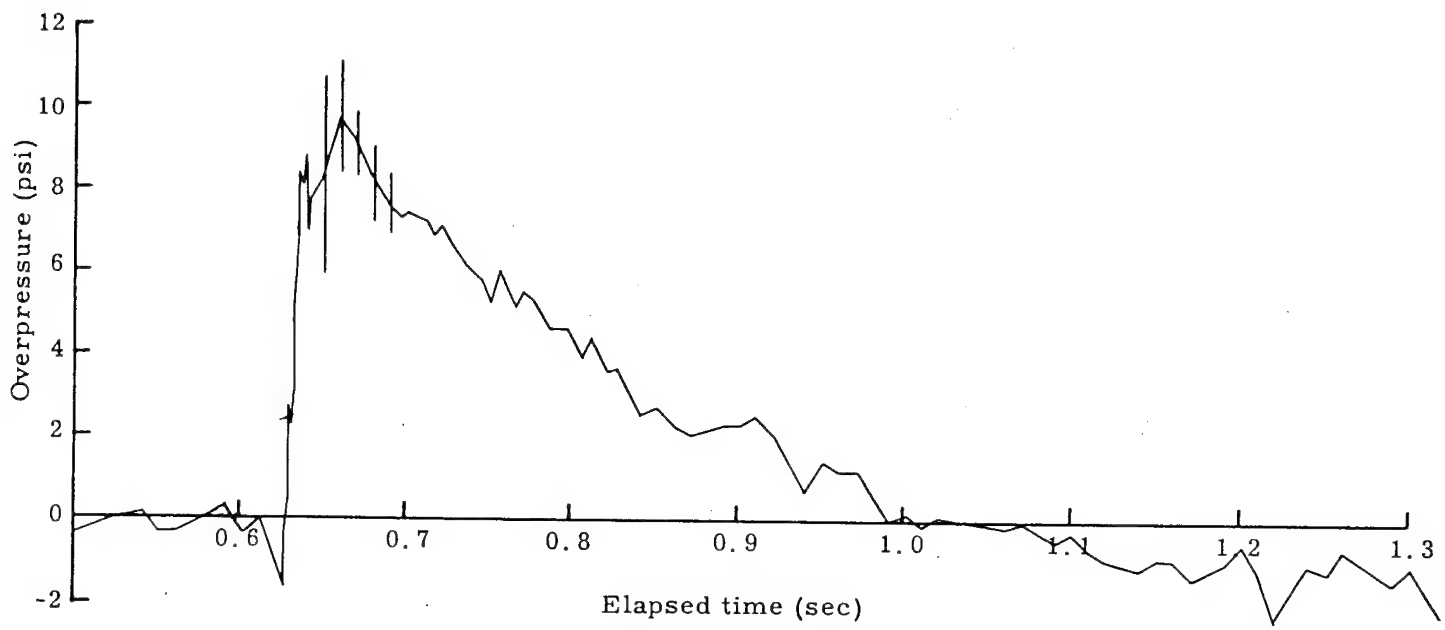


Fig. 23. -- Shot Baker (B215R) (gauge 15 ft above ground) (distance from ground zero: 876 ft)

[redacted]

[redacted]

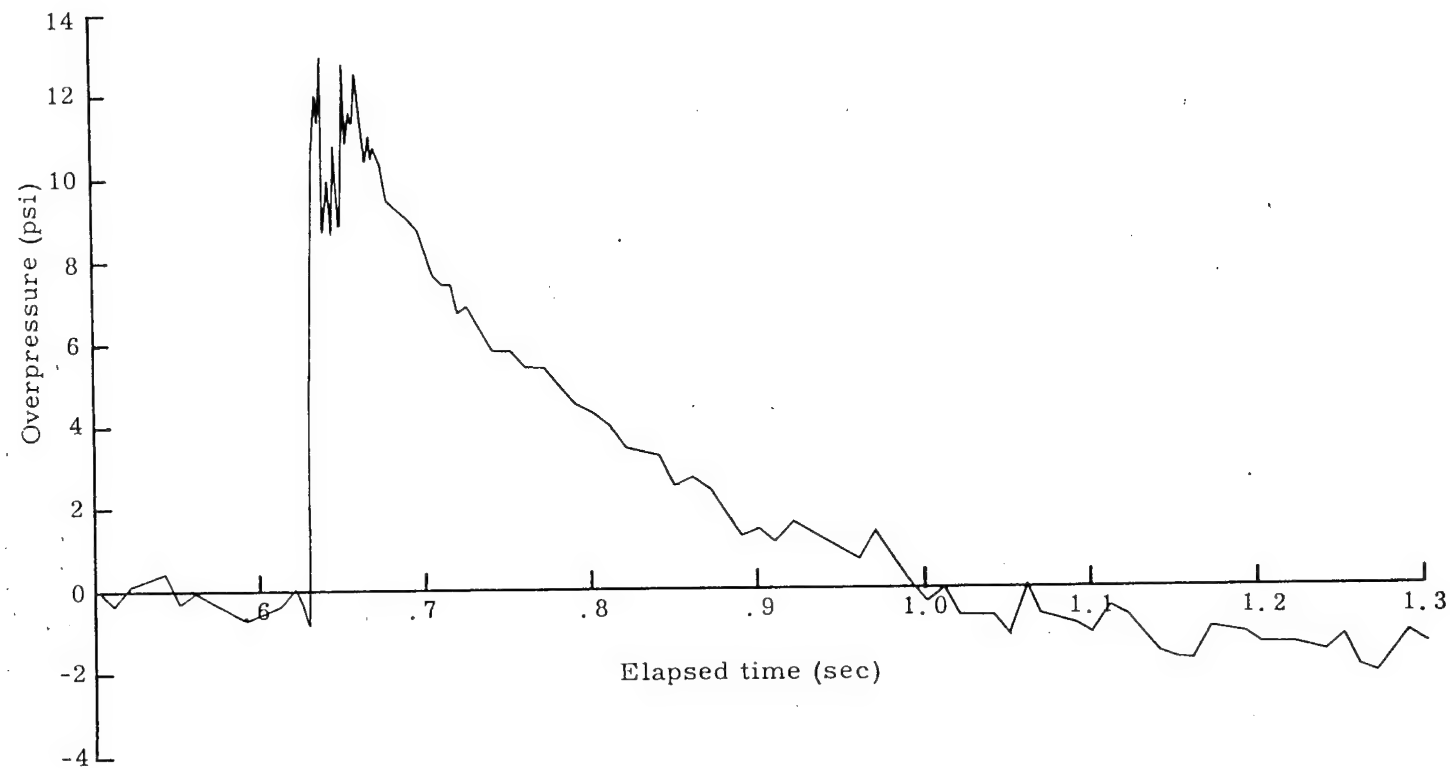


Fig. 24. -- Shot Baker (B215L) (gauge 15 ft above ground) (distance from ground zero: 870 ft)

[redacted]

[redacted]

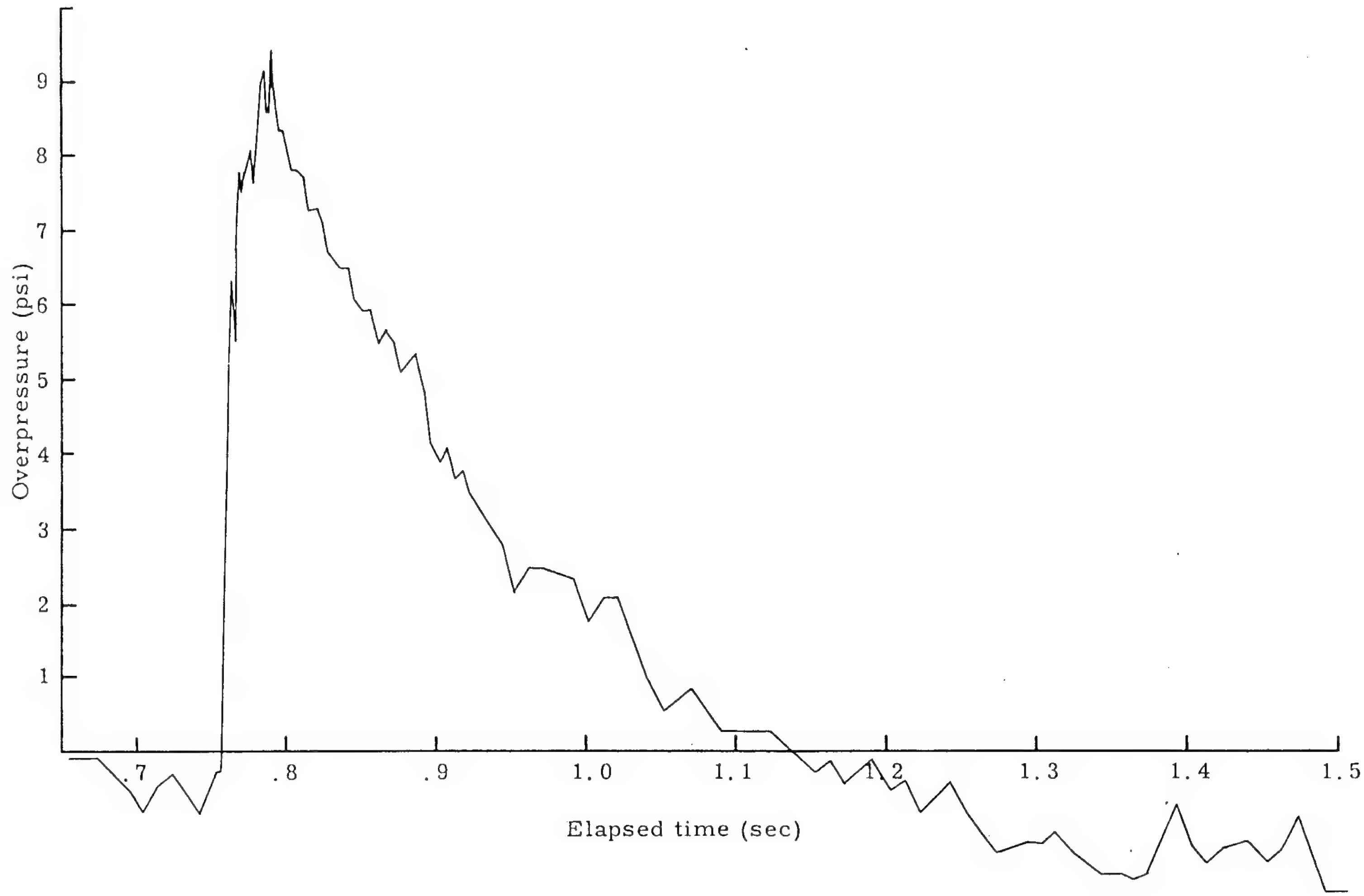


Fig. 25. -- Shot Baker (DS) (ground baffle) (distance from ground zero: 1,123 ft)

[redacted]

[redacted]

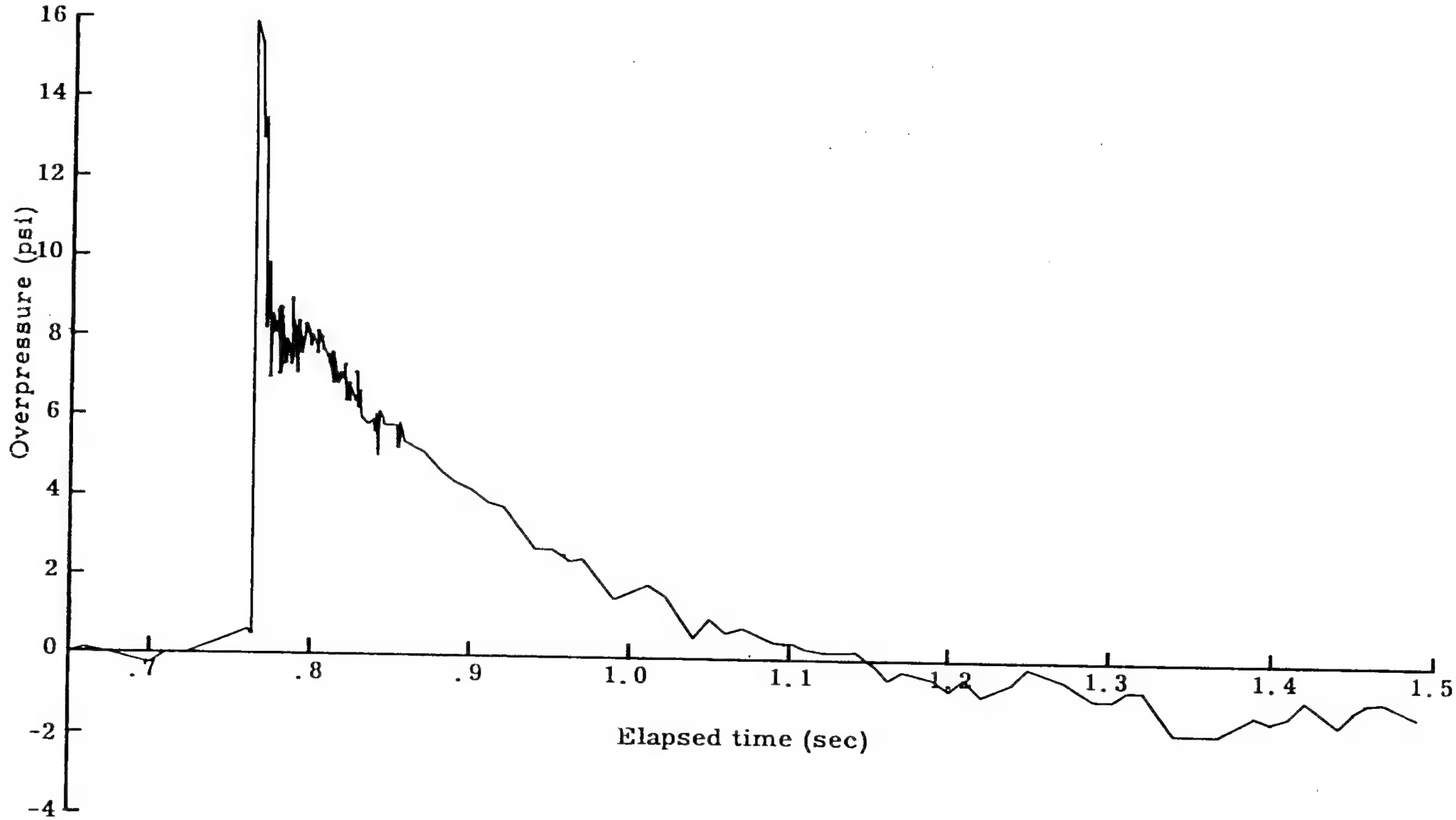


Fig. 26. -- Shot Baker (D15L) (gauge 15 ft above ground) (distance from ground zero: 1,123 ft)

[redacted]

[redacted]

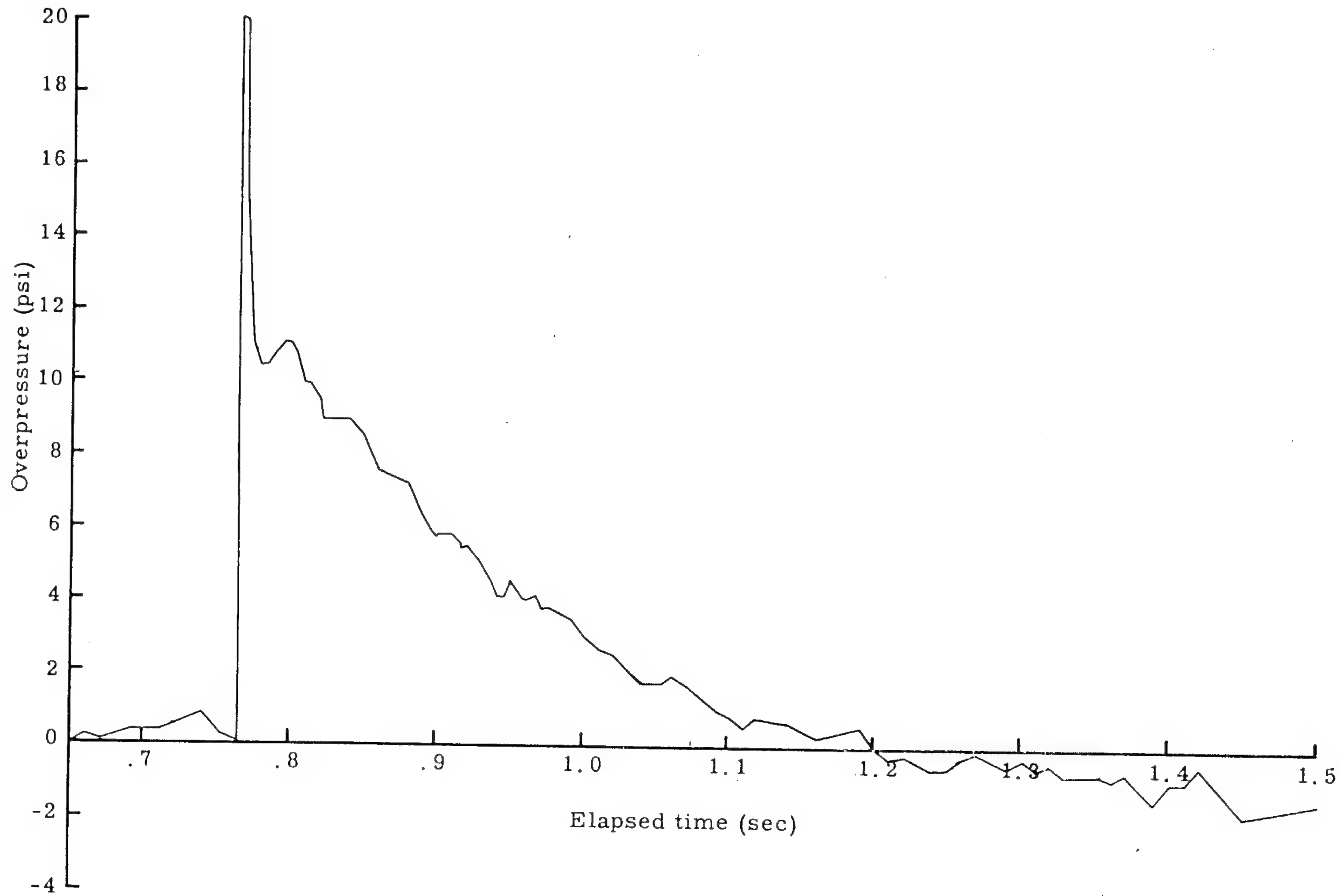


Fig. 27. -- Shot Baker (D15R) (gauge 15 ft above ground) (distance from ground zero: 1, 123 ft)

[redacted]

[redacted]

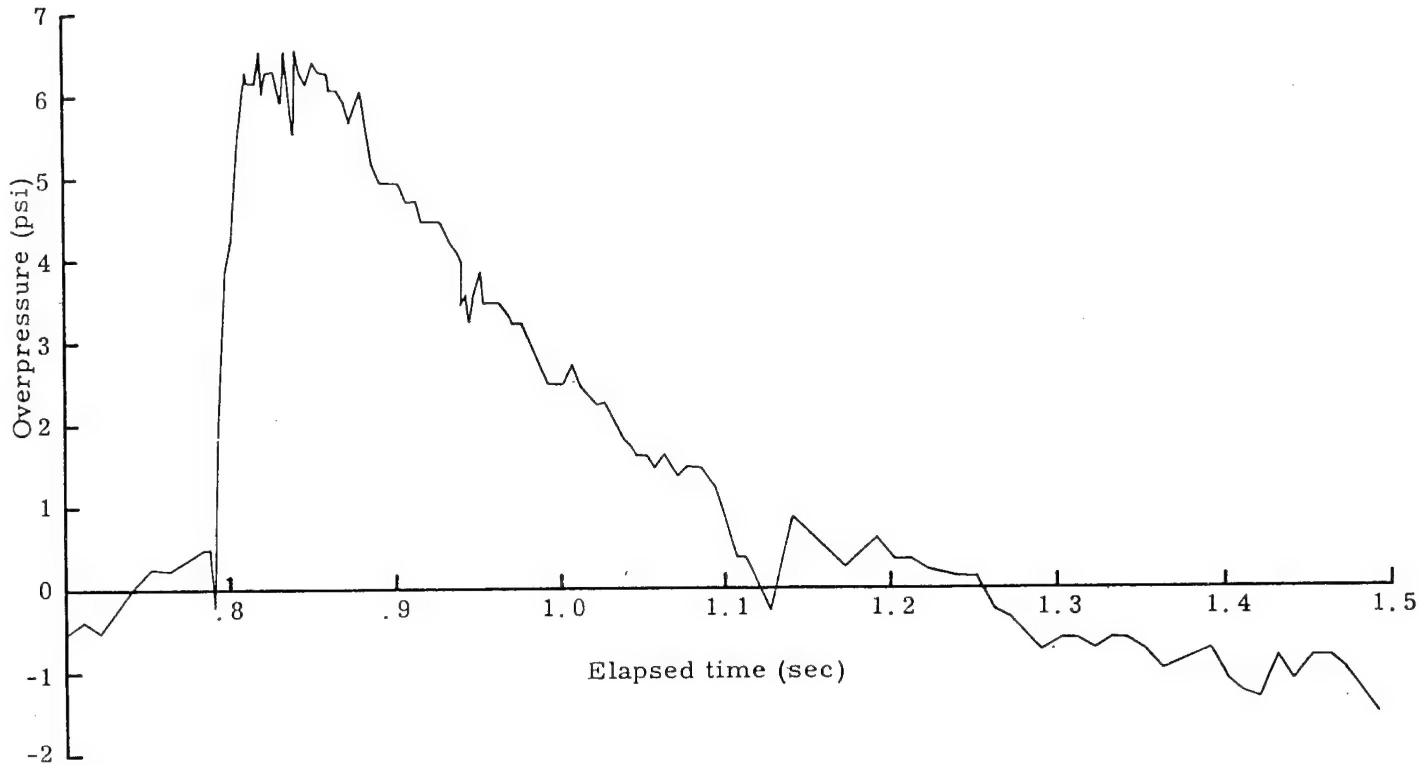


Fig. 28. -- Shot Baker (A2S) (ground baffle) (distance from ground zero: 1,243 ft)

[redacted]

[redacted]

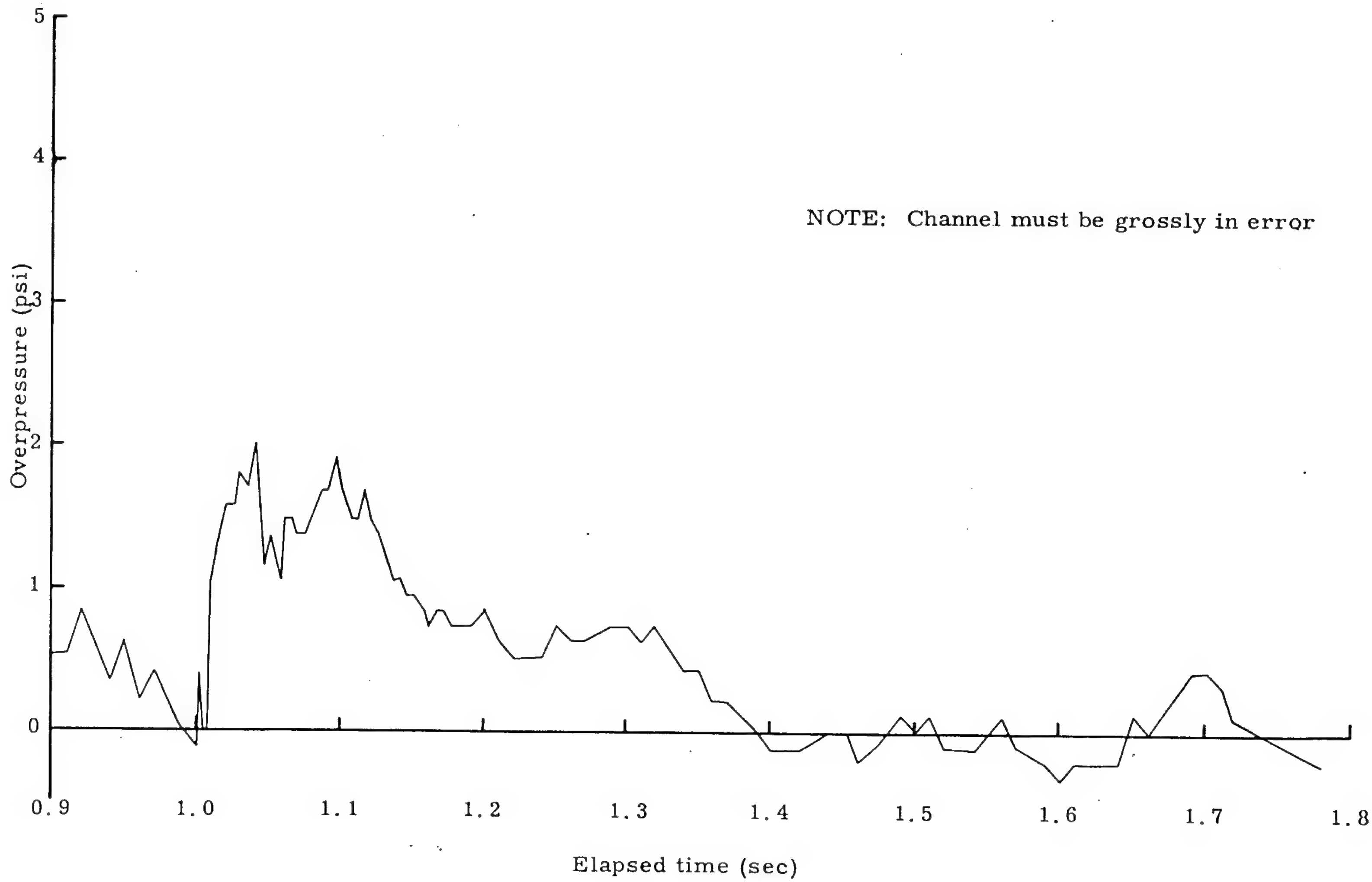


Fig. 29. -- Shot Baker (ES) (ground baffle) (distance from ground zero: 1, 543 ft)

[redacted]

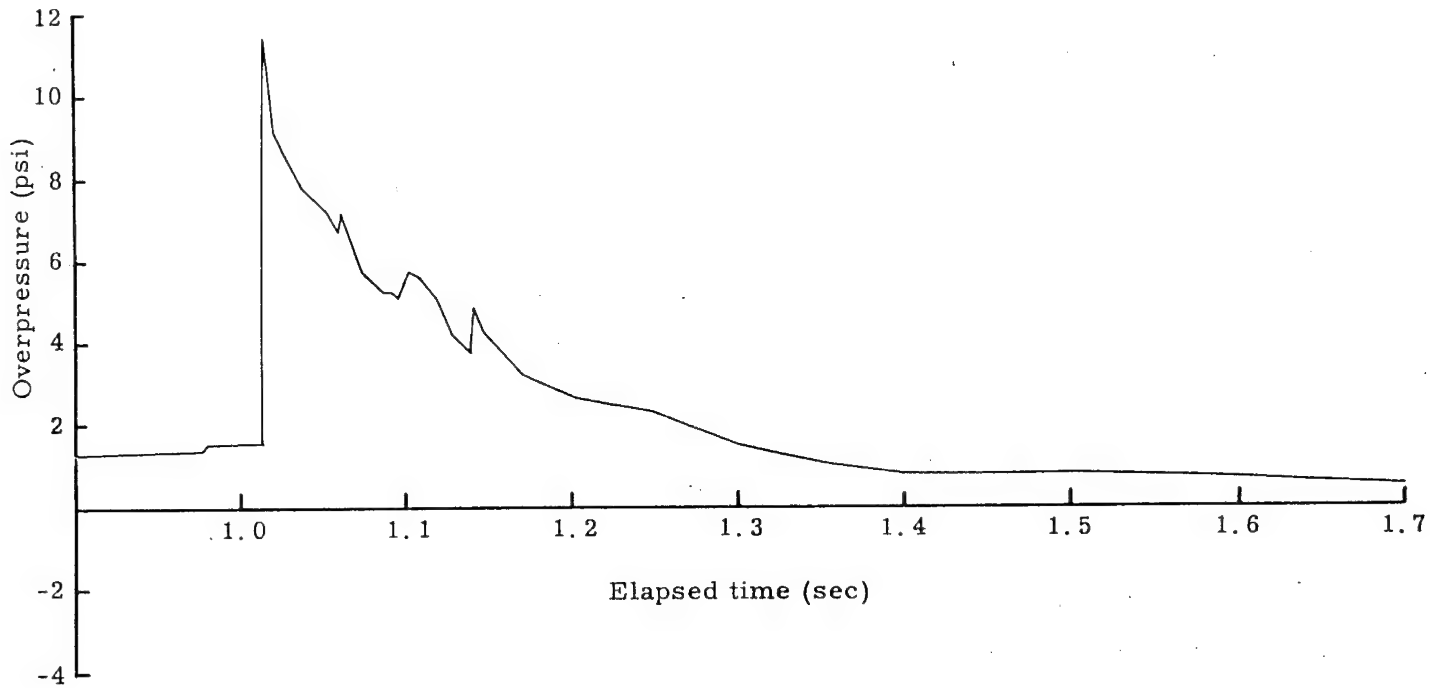


Fig. 30. -- Shot Baker (E15L) (gauge 15 ft above ground) (distance from ground zero: 1, 543 ft)

[redacted]

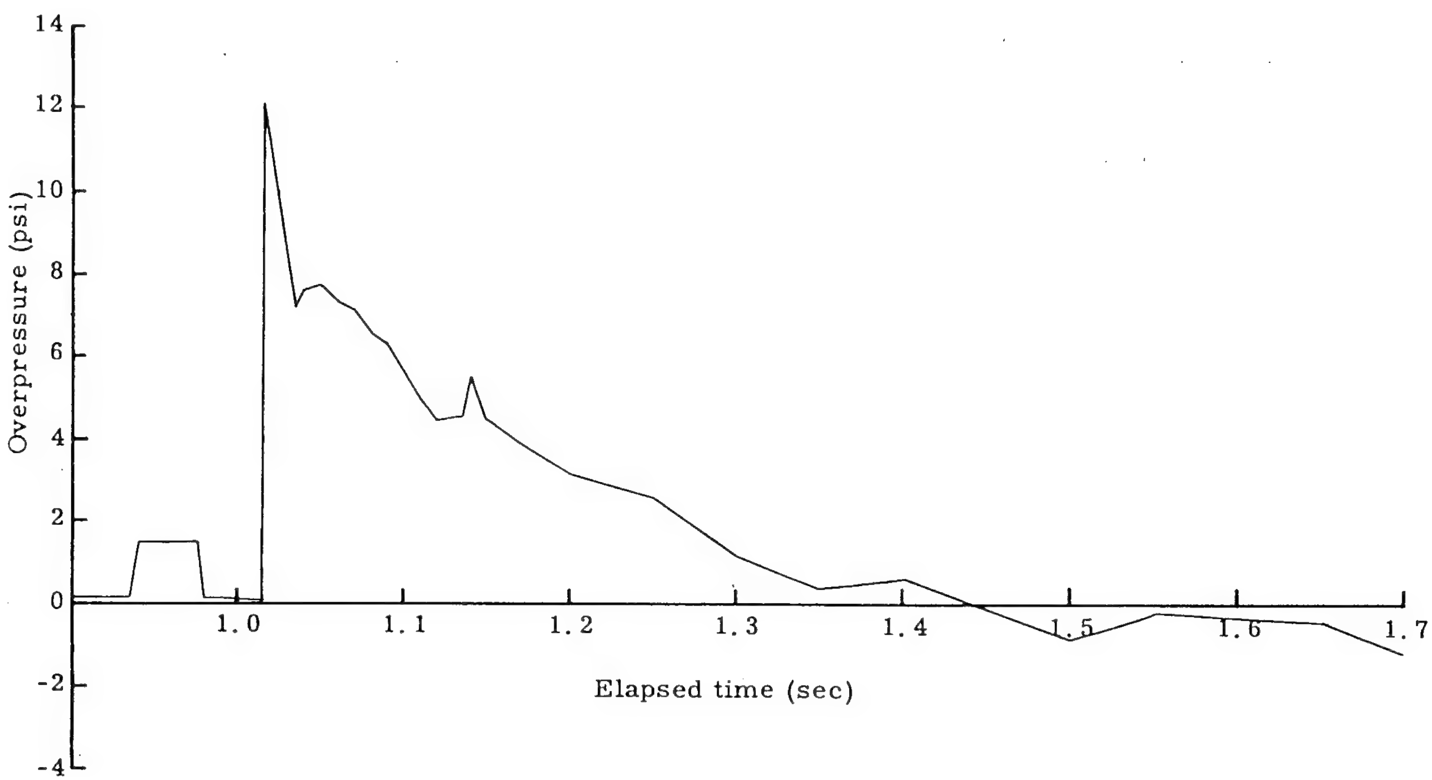


Fig. 31. -- Shot Baker (E15R) (gauge 15 ft above ground) (distance from ground zero: 1,543 ft)

[redacted]

[redacted]

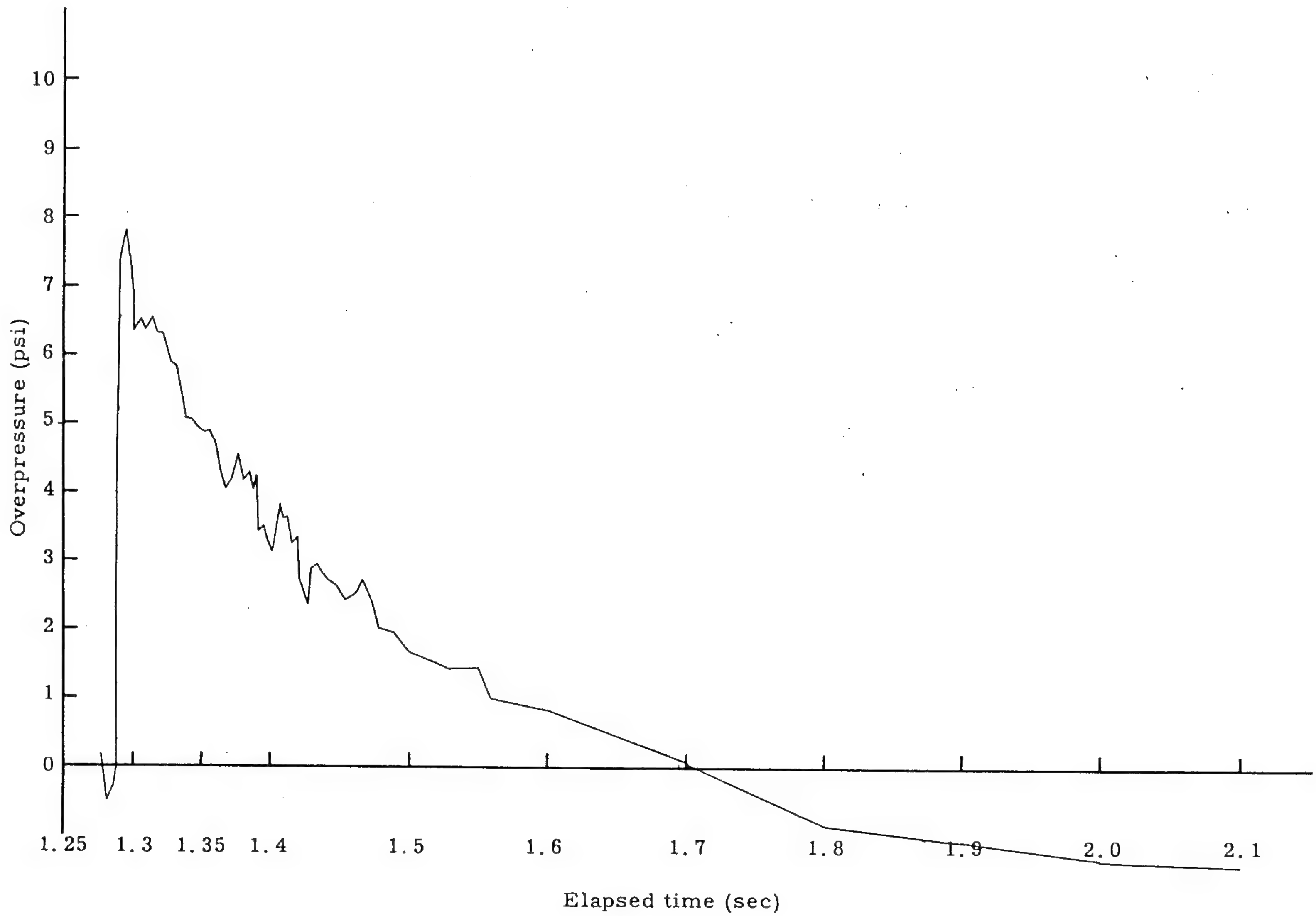


Fig. 32. -- Shot Baker (FS) (ground baffle) (distance from ground zero: 1,953 ft)

[redacted]

[redacted]

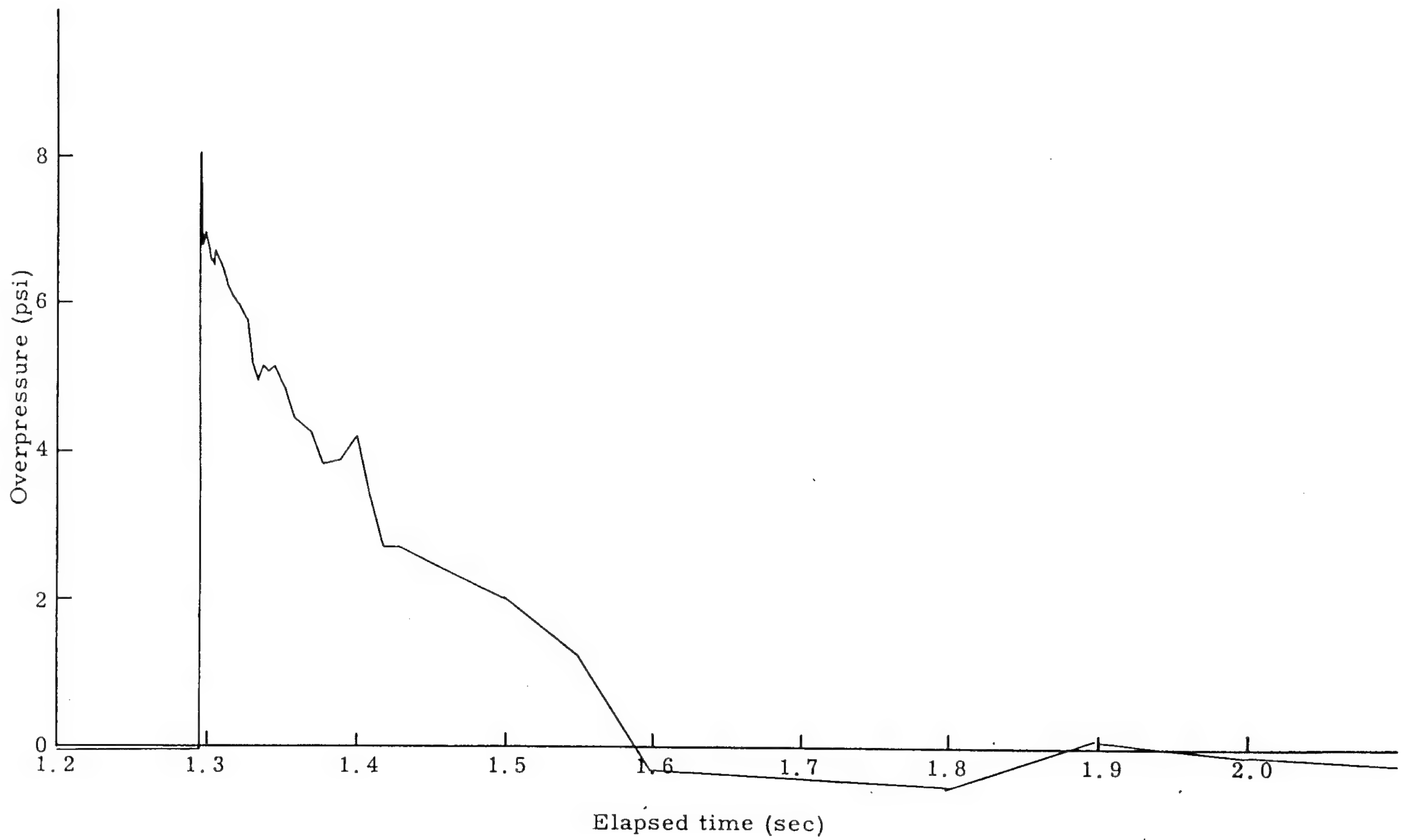


Fig. 33. -- Shot Baker (F15R) (gauge 15 ft above ground) (distance from ground zero: 1,953 ft)

[redacted]

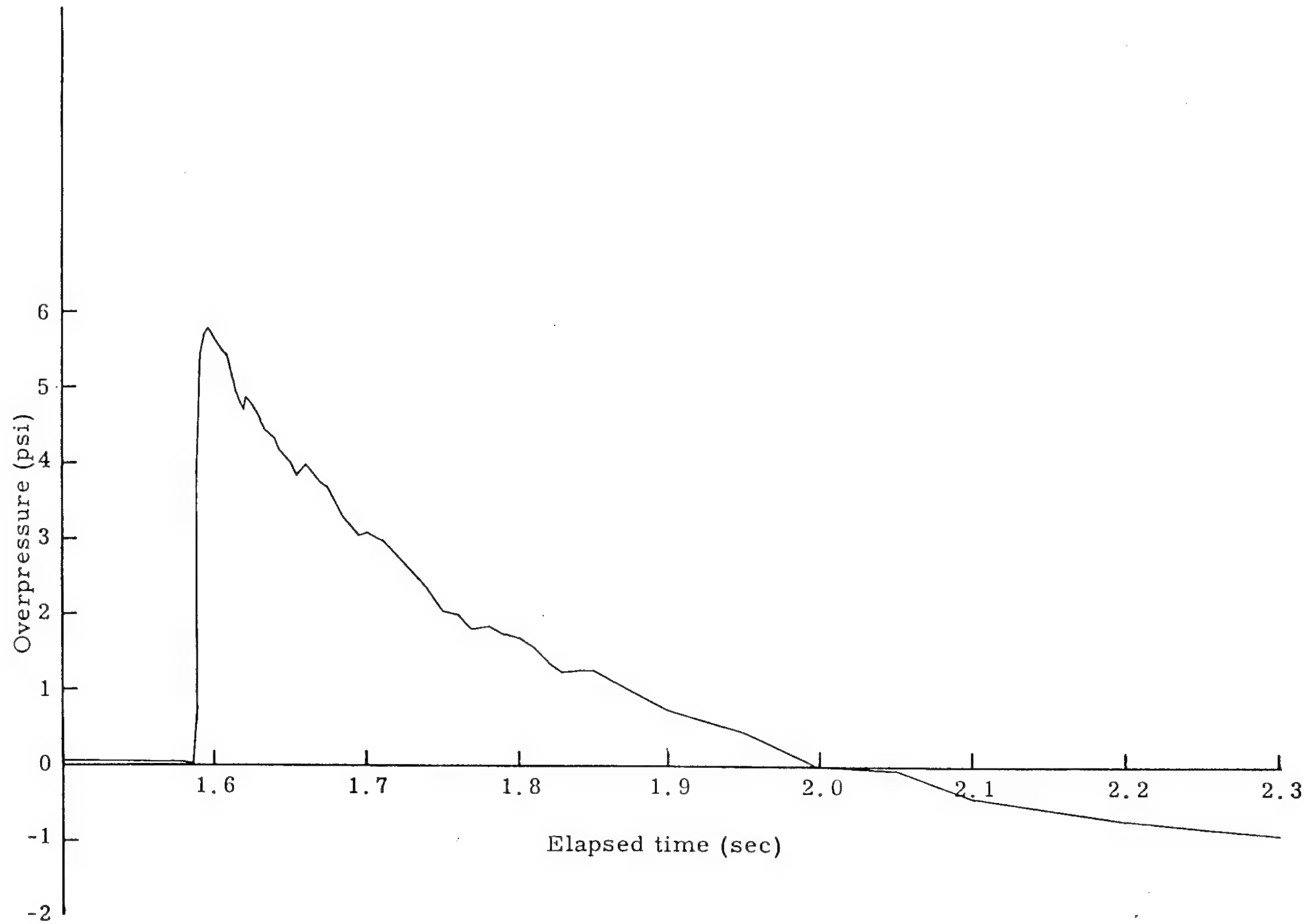


Fig. 34. -- Shot Baker (GS) (ground baffle) (distance from ground zero: 2,361 ft)

[redacted]

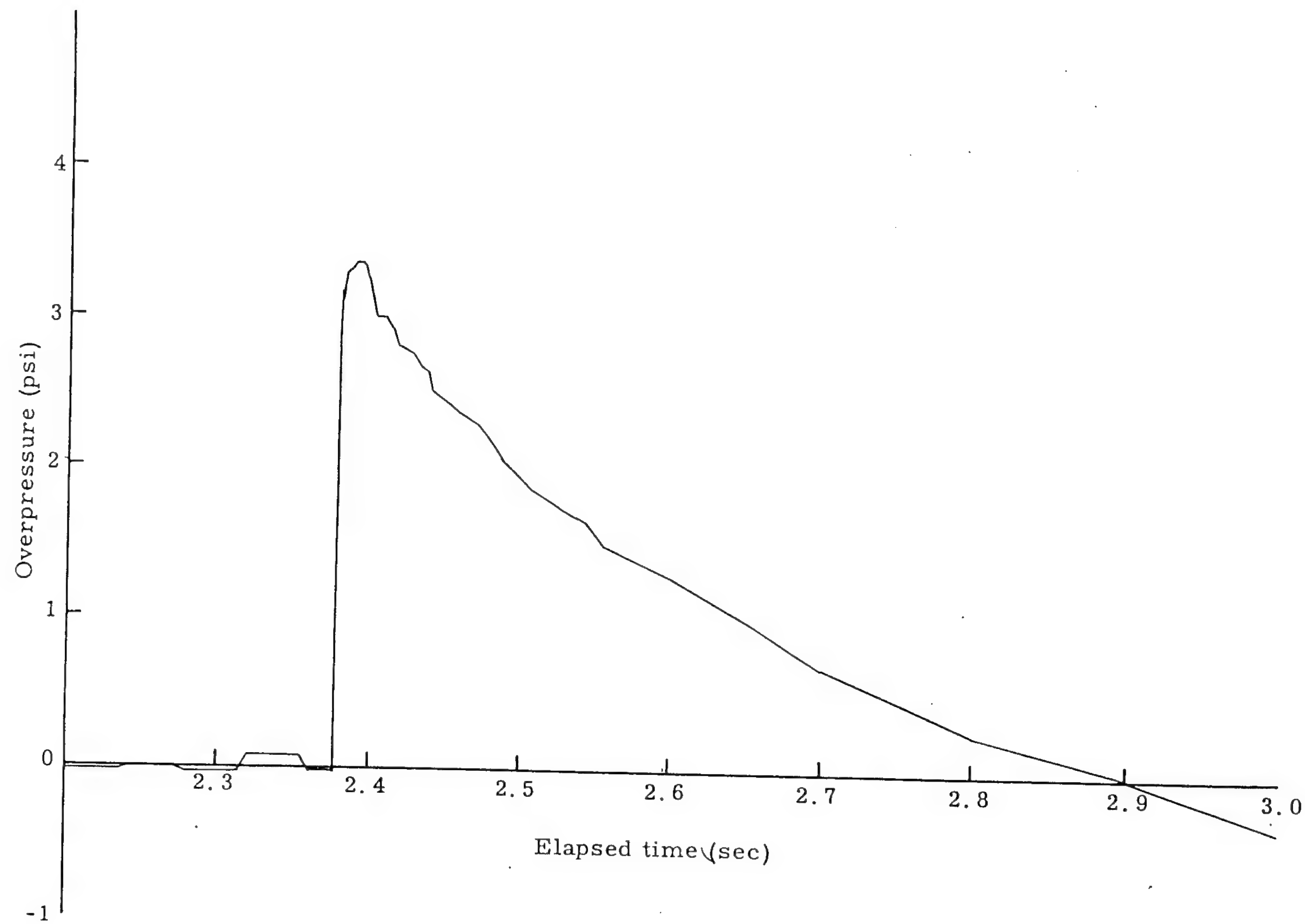


Fig. 35. -- Shot Baker (HS) (ground baffle) (distance from ground zero: 3,375 ft)

[redacted]

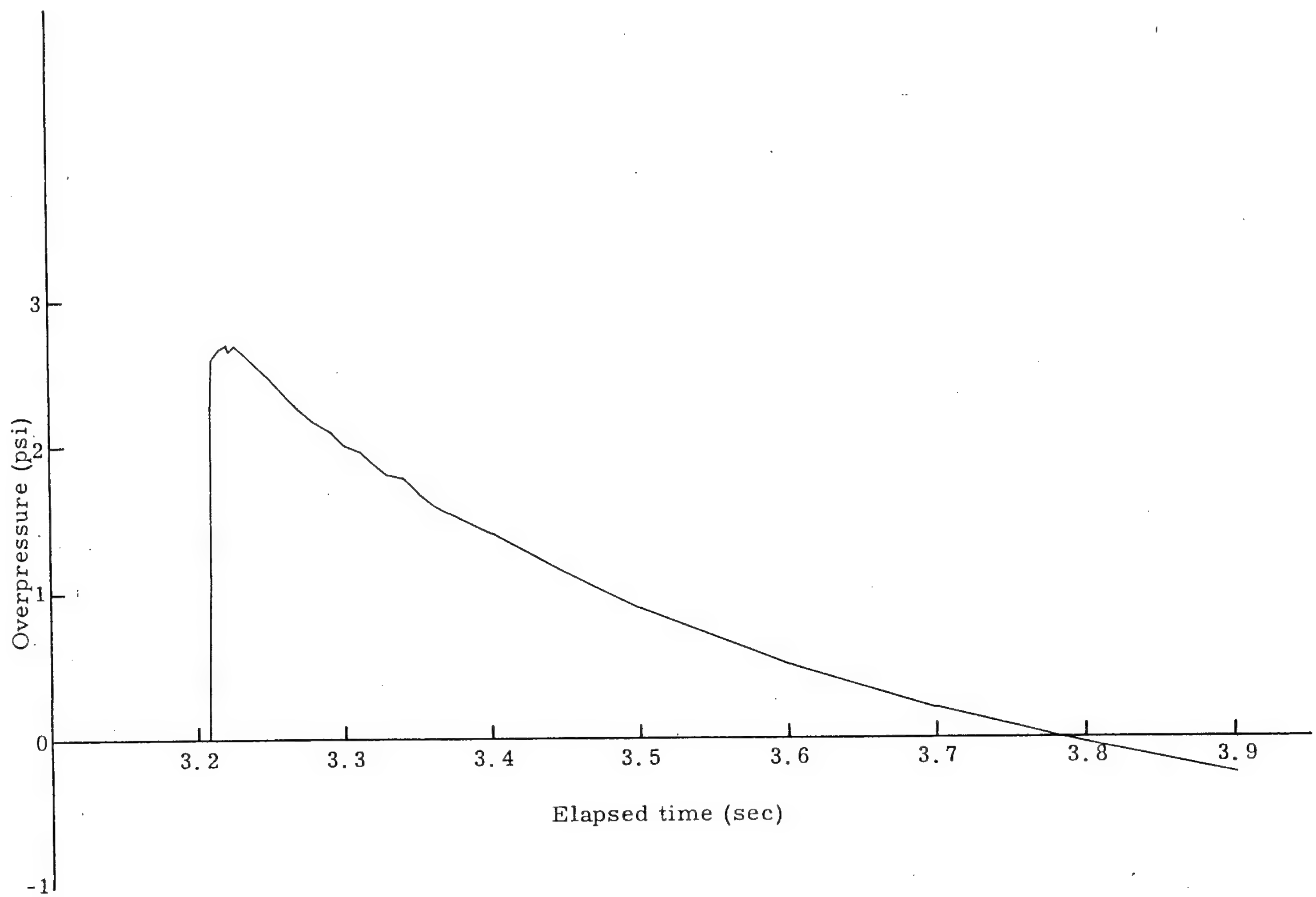


Fig. 36. -- Shot Baker (IS) (ground baffle) (distance from ground zero: 4, 380 ft)

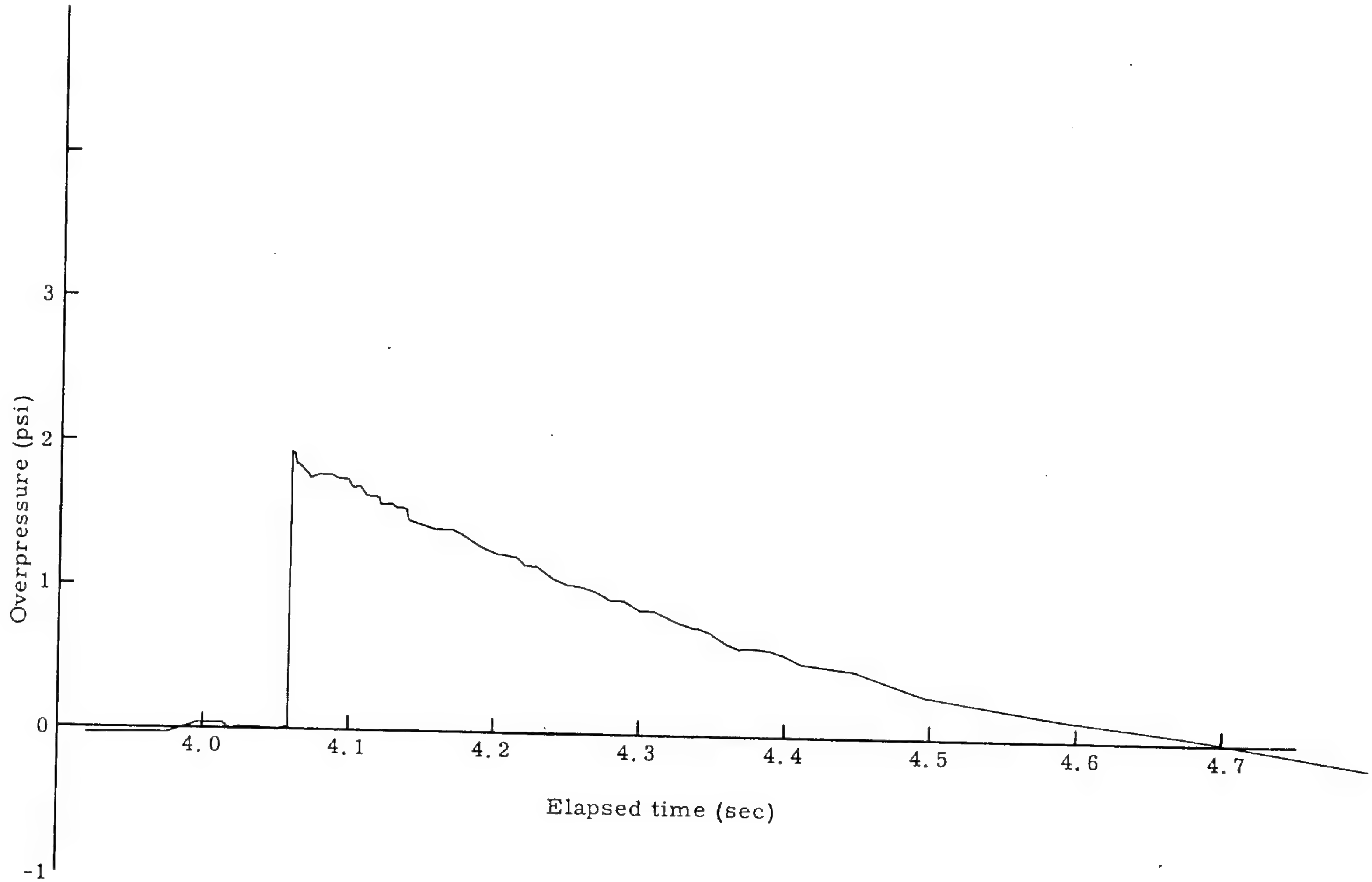


Fig. 37. -- Shot Baker (JS) (ground baffle) (distance from ground zero: 5, 385 ft)

[redacted]

Pressure-Time Data
Shot Charlie

[redacted]

[redacted]

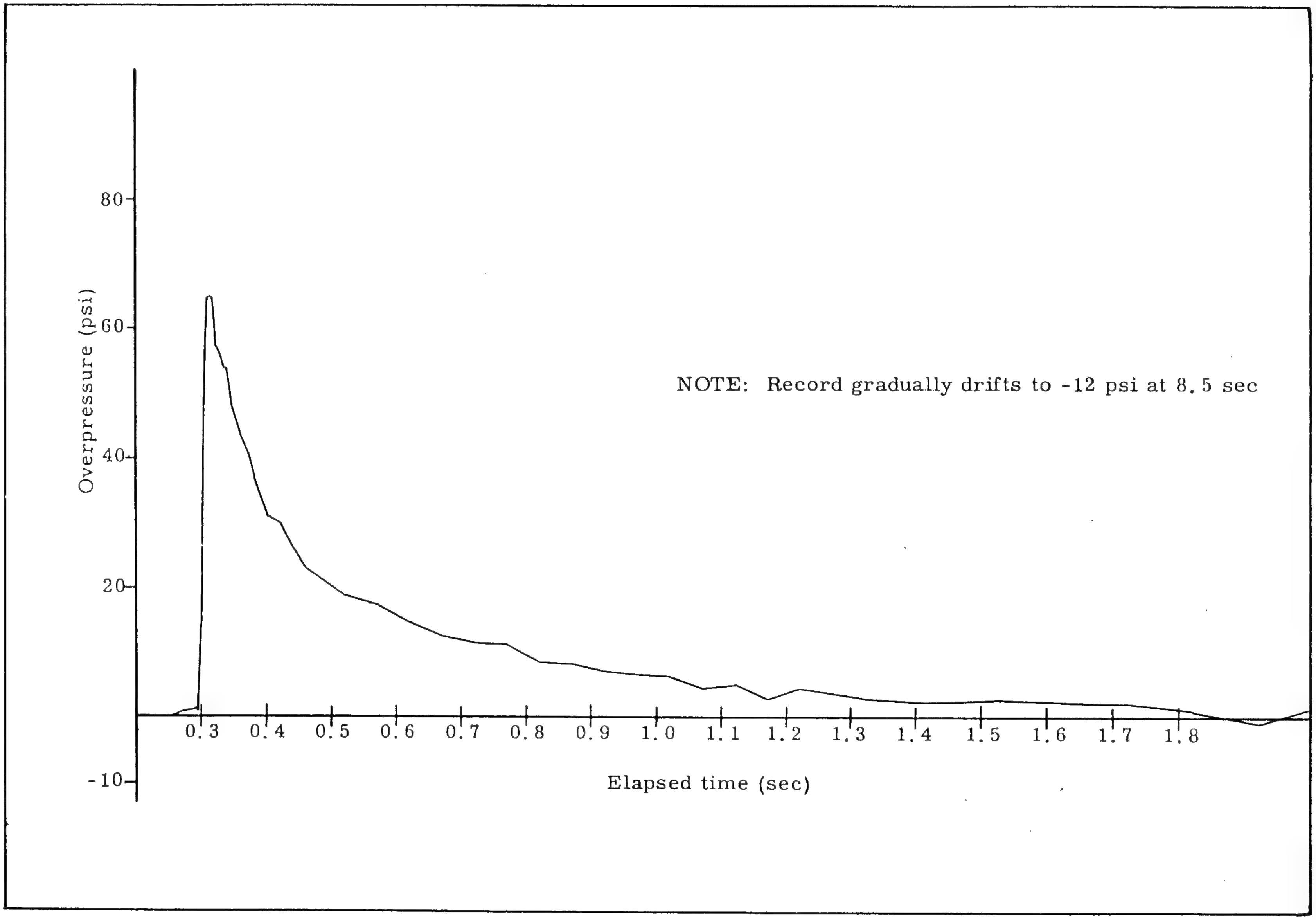


Fig. 38. -- Shot Charlie (A3S) (ground baffle) (distance from ground zero: 163 ft)

[redacted]

[redacted]

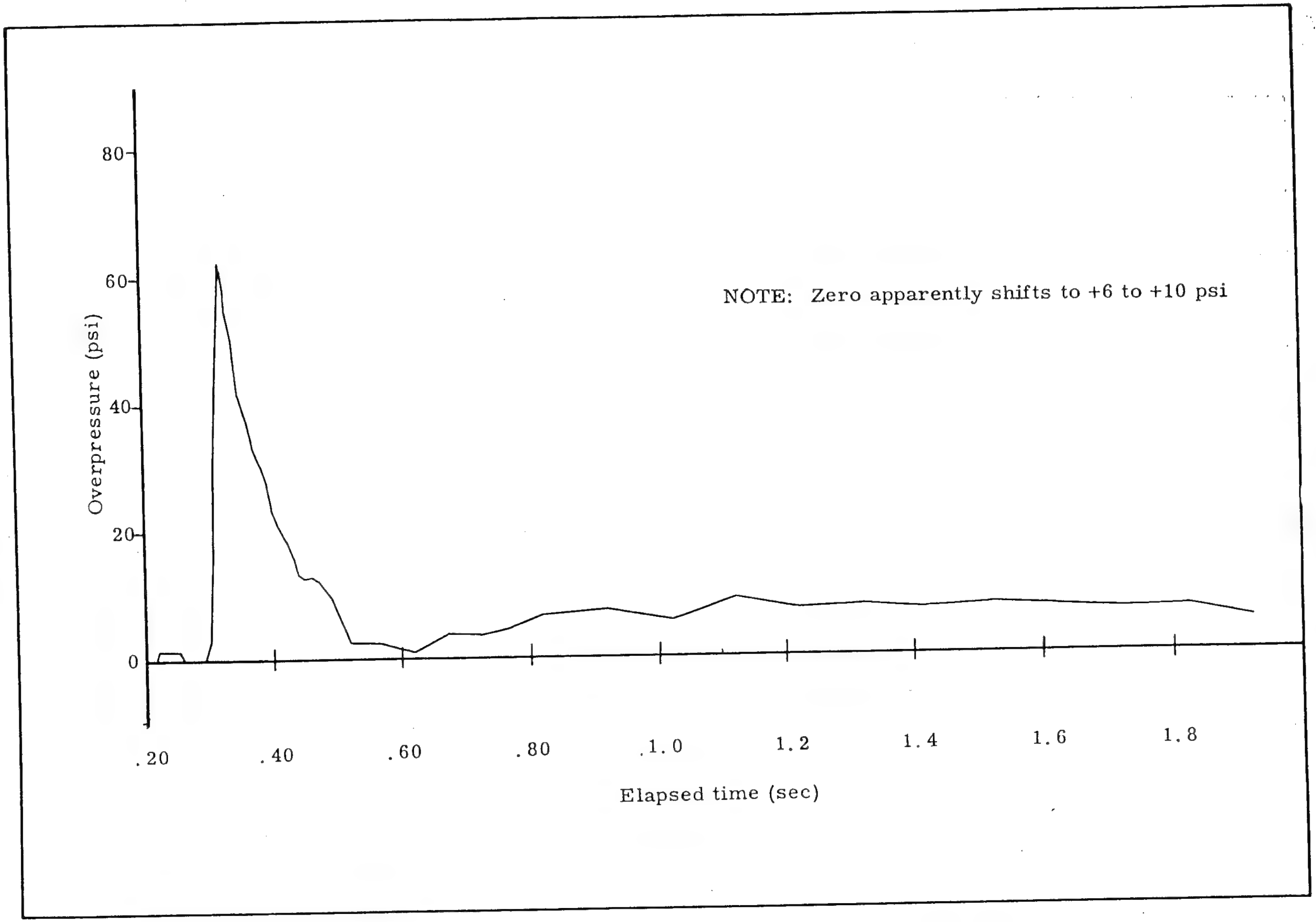


Fig. 39. -- Shot Charlie (B3S) (ground baffle) (distance from ground zero: 298 ft)

[redacted]

[redacted]

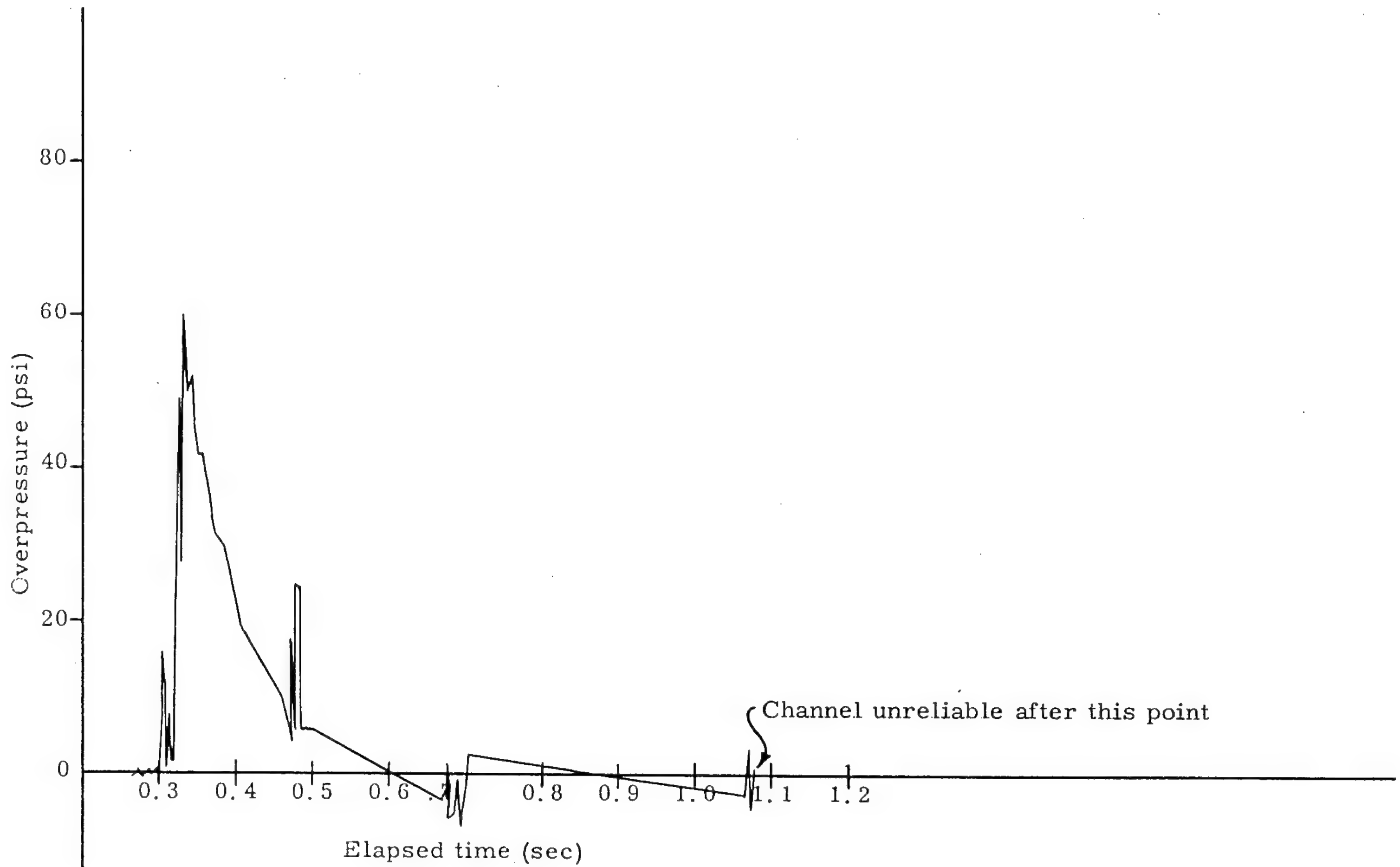


Fig. 40. -- Shot Charlie (B315L) (gauge 15 ft above ground) (distance from ground zero: 281 ft)

[redacted]

[redacted]

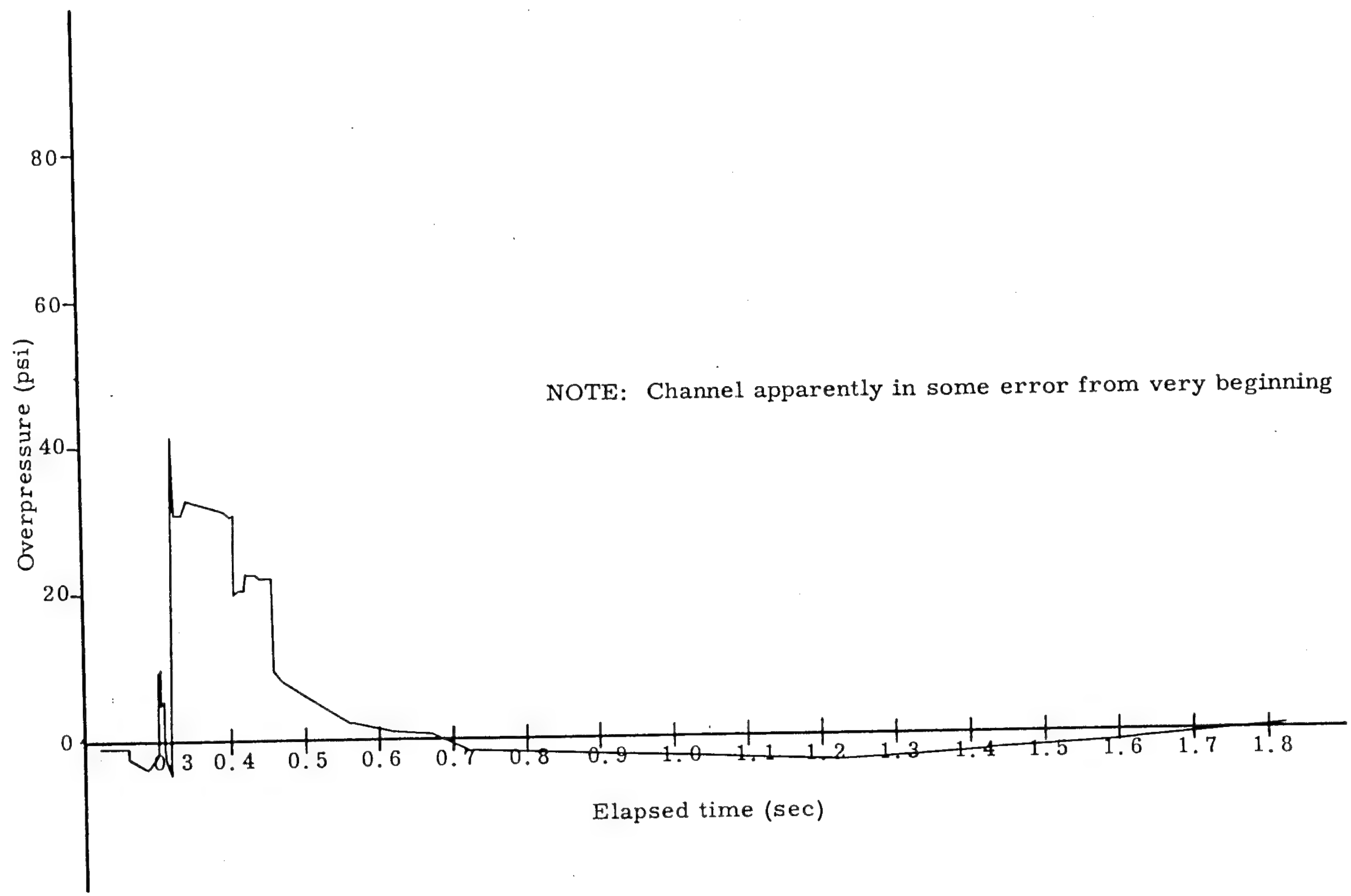


Fig. 41. -- Shot Charlie (B315R) (gauge 15 ft above ground) (distance from ground zero: 281 ft).

[redacted]

[redacted]

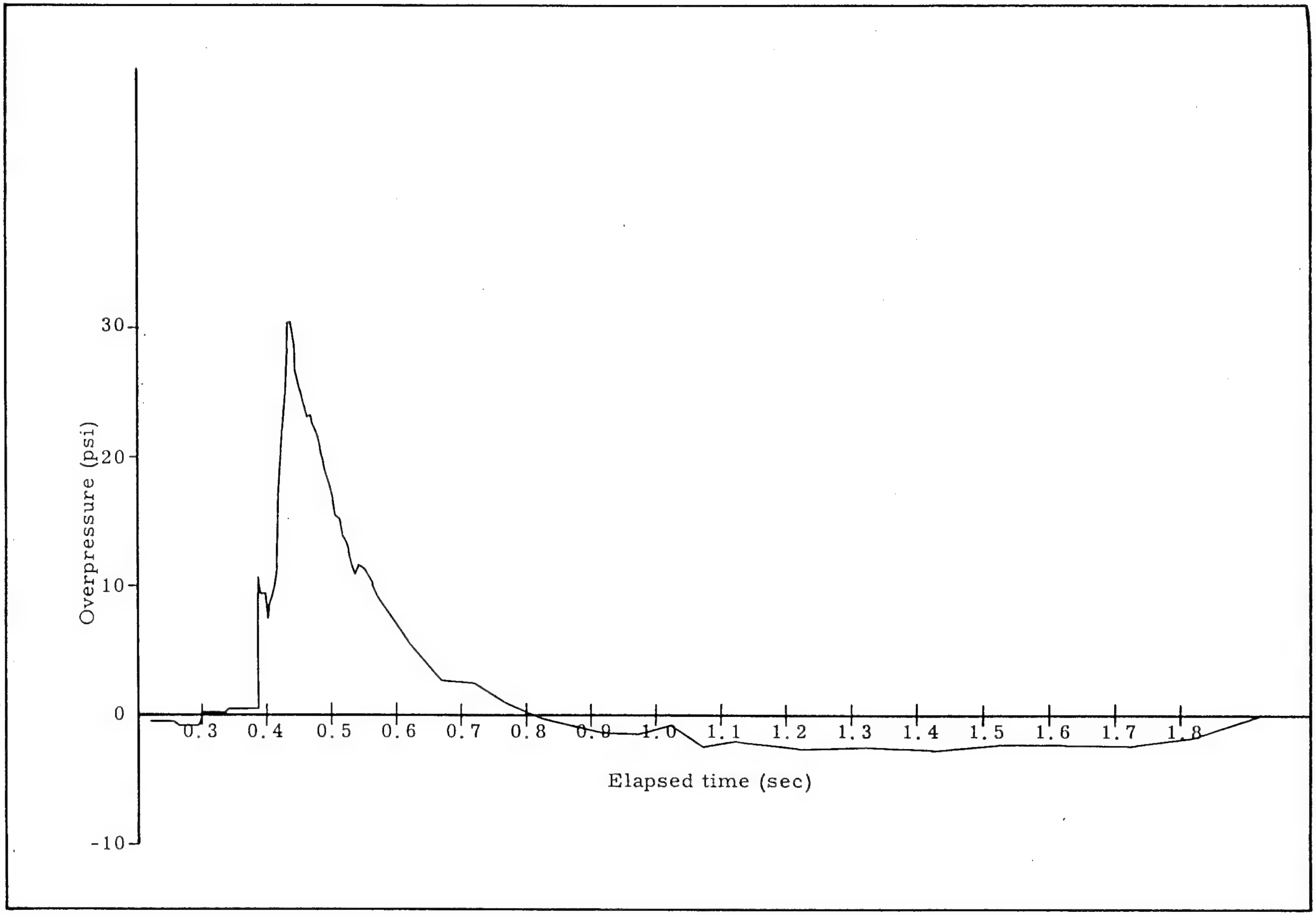


Fig. 42. -- Shot Charlie (CS) (ground baffle) (distance from ground zero: 768 ft)

[redacted]

[redacted]

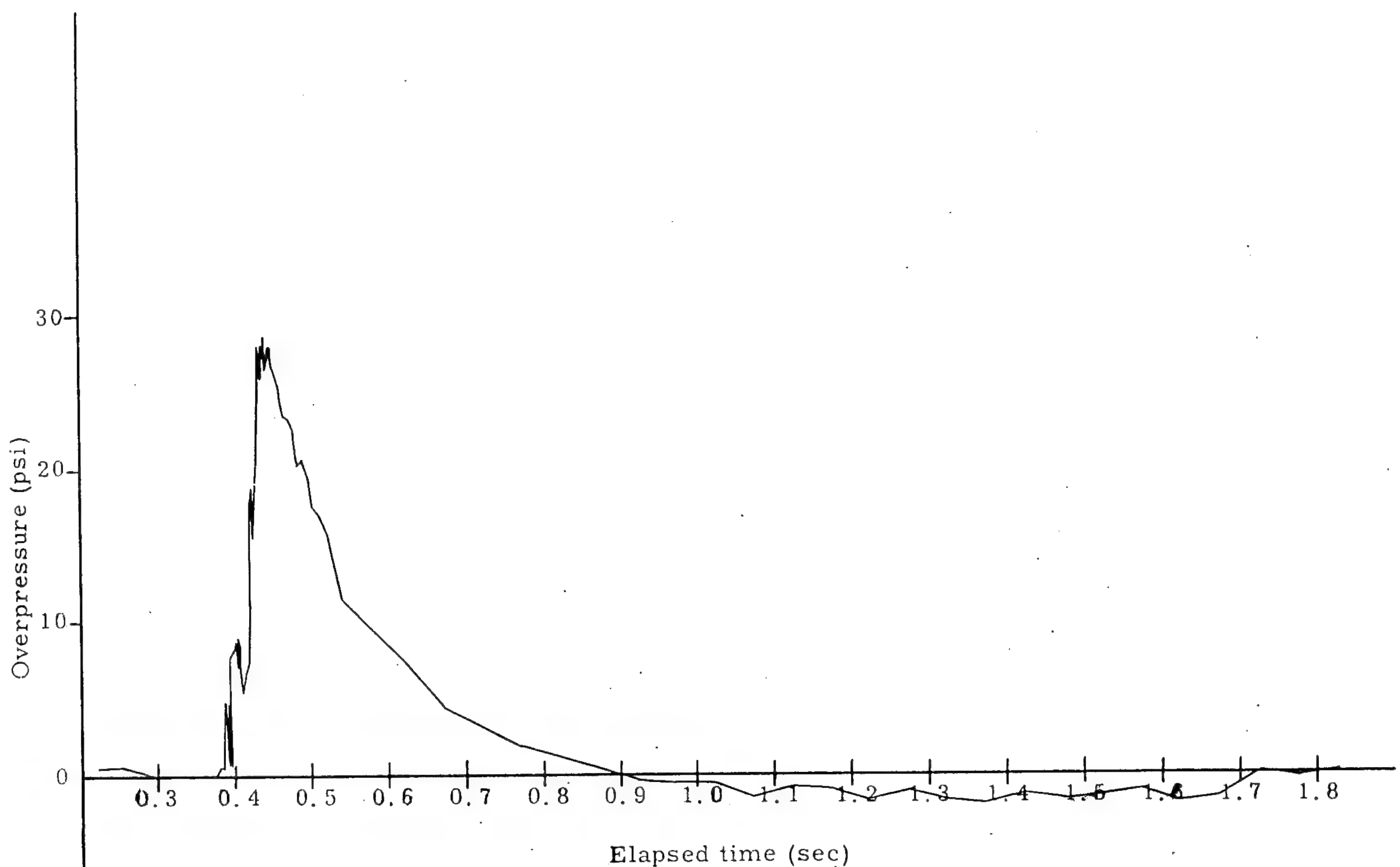


Fig. 43. -- Shot Charlie (C15L) (gauge 15 ft above ground) (distance from ground zero: 768 ft)

[redacted]

[redacted]

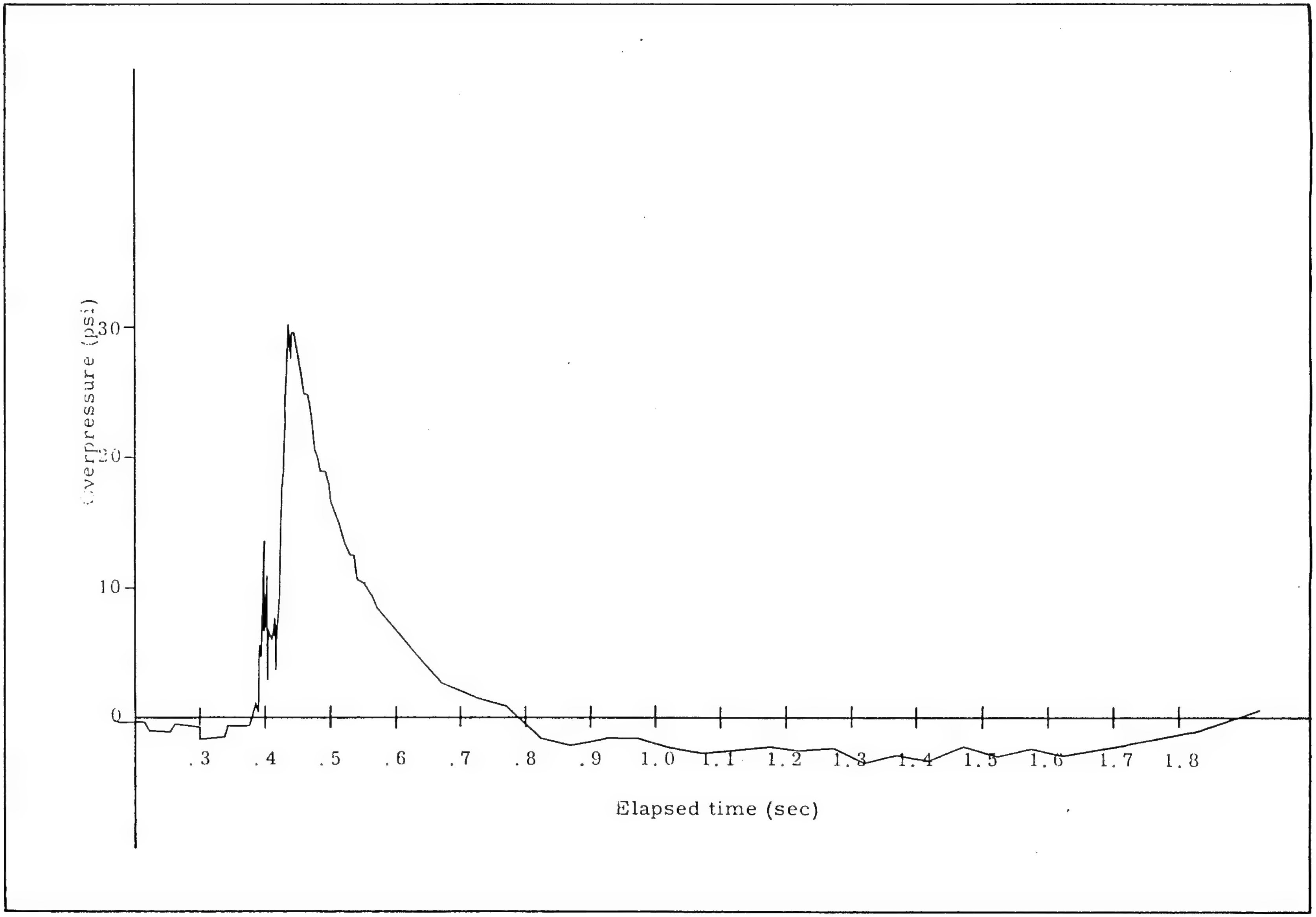


Fig. 44. -- Shot Charlie (C15R) (gauge 15 ft above ground) (distance from ground zero: 768 ft)

[redacted]

[redacted]

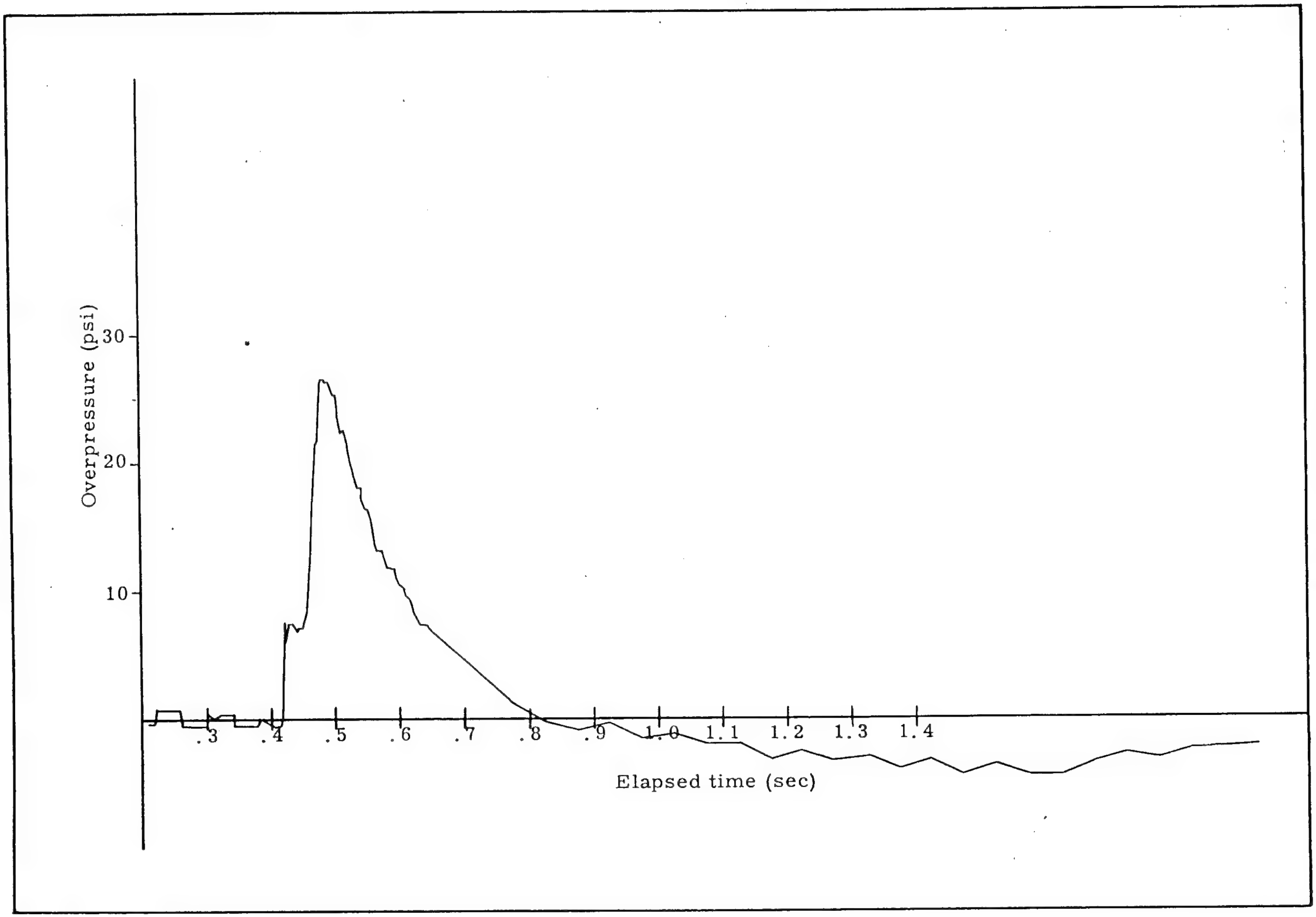


Fig. 45. -- Shot Charlie (B2S) (gauge 15 ft above ground) (distance from ground zero: 877 ft)

[redacted]

[redacted]

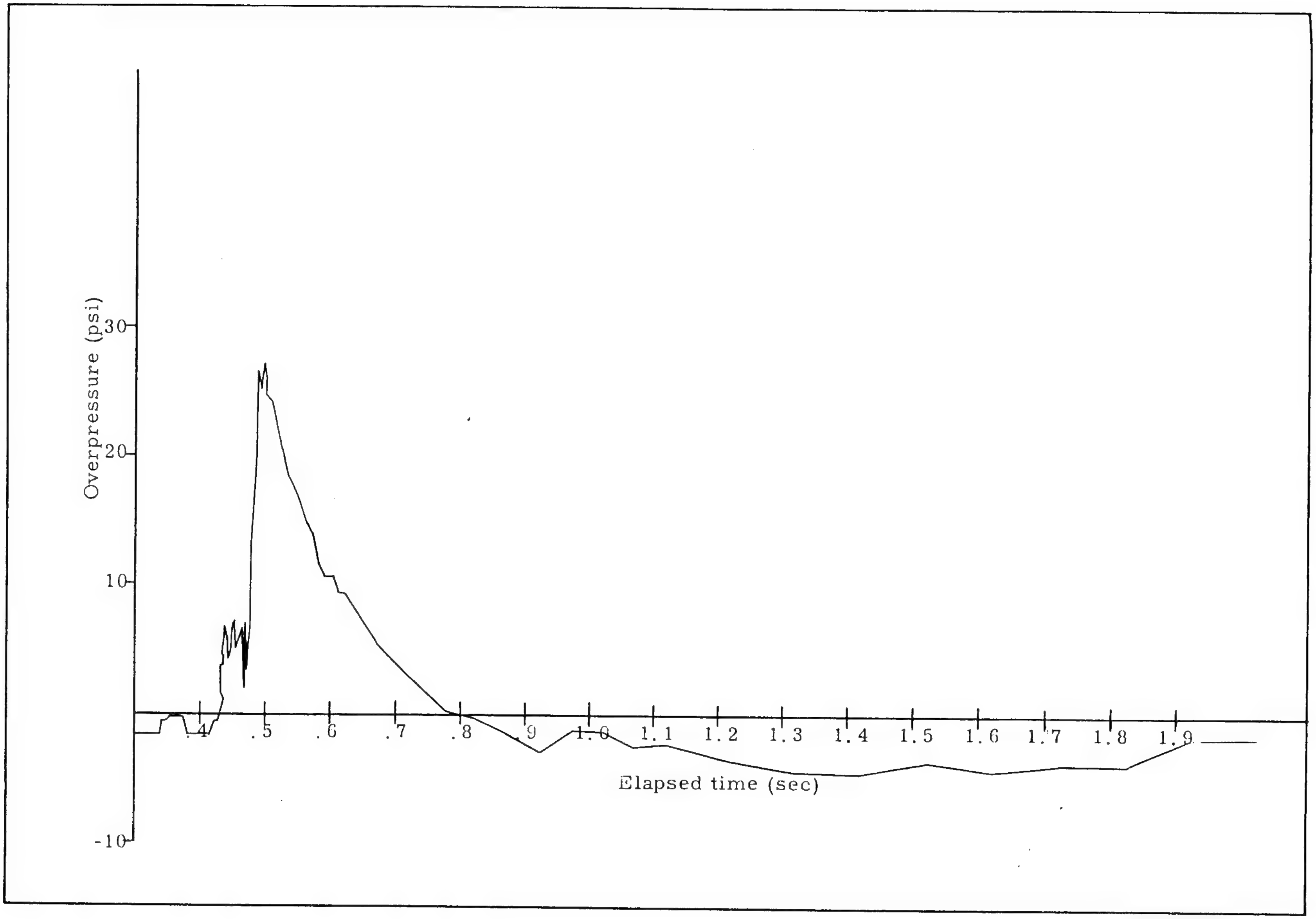


Fig. 46. -- Shot Charlie (B215L) (gauge 15 ft above ground) (distance from ground zero: 894 ft)

[redacted]

[redacted]

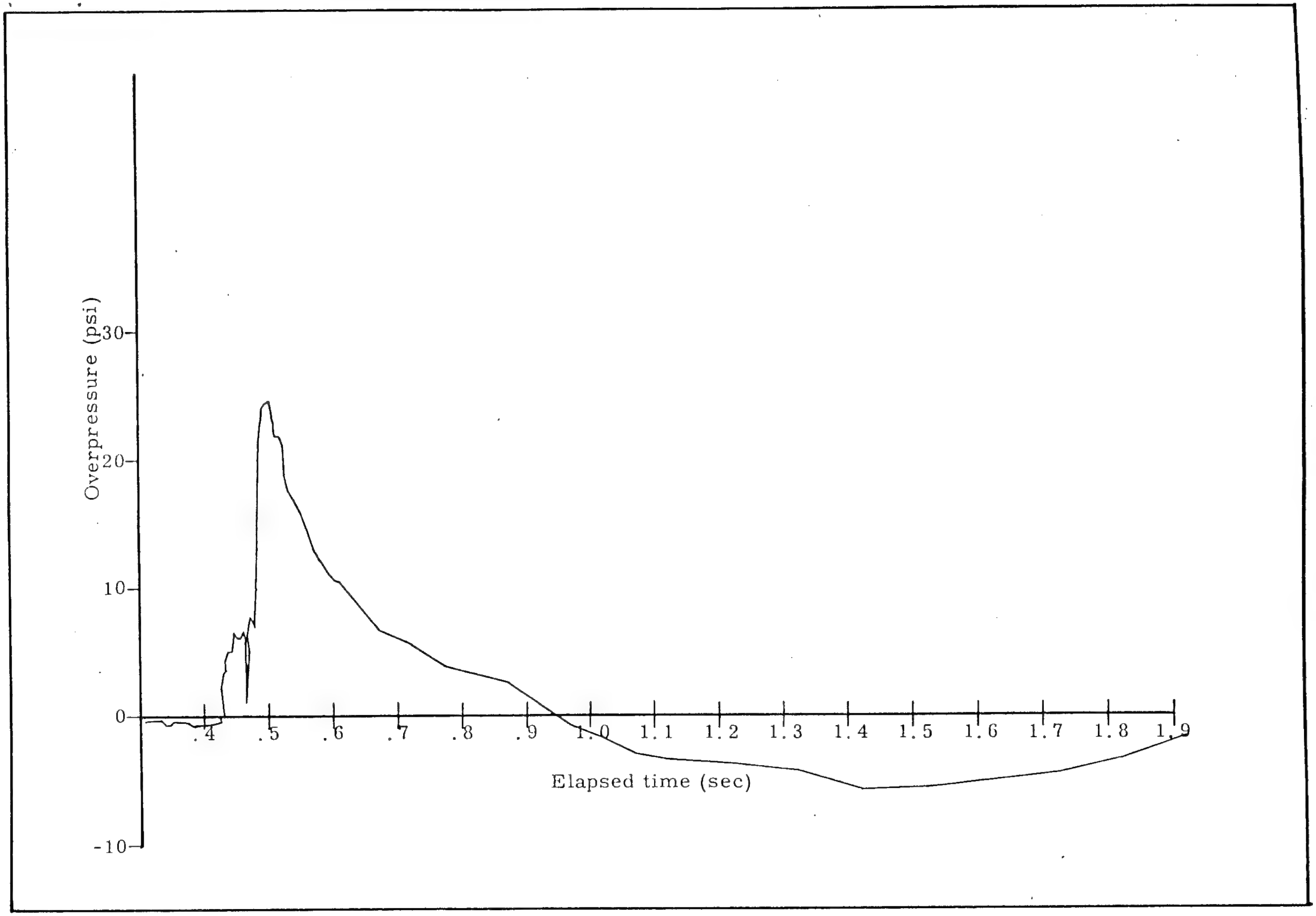


Fig. 47. -- Shot Charlie (B215R) (gauge 15 ft above ground) (distance from ground zero: 894 ft)

[redacted]

[redacted]

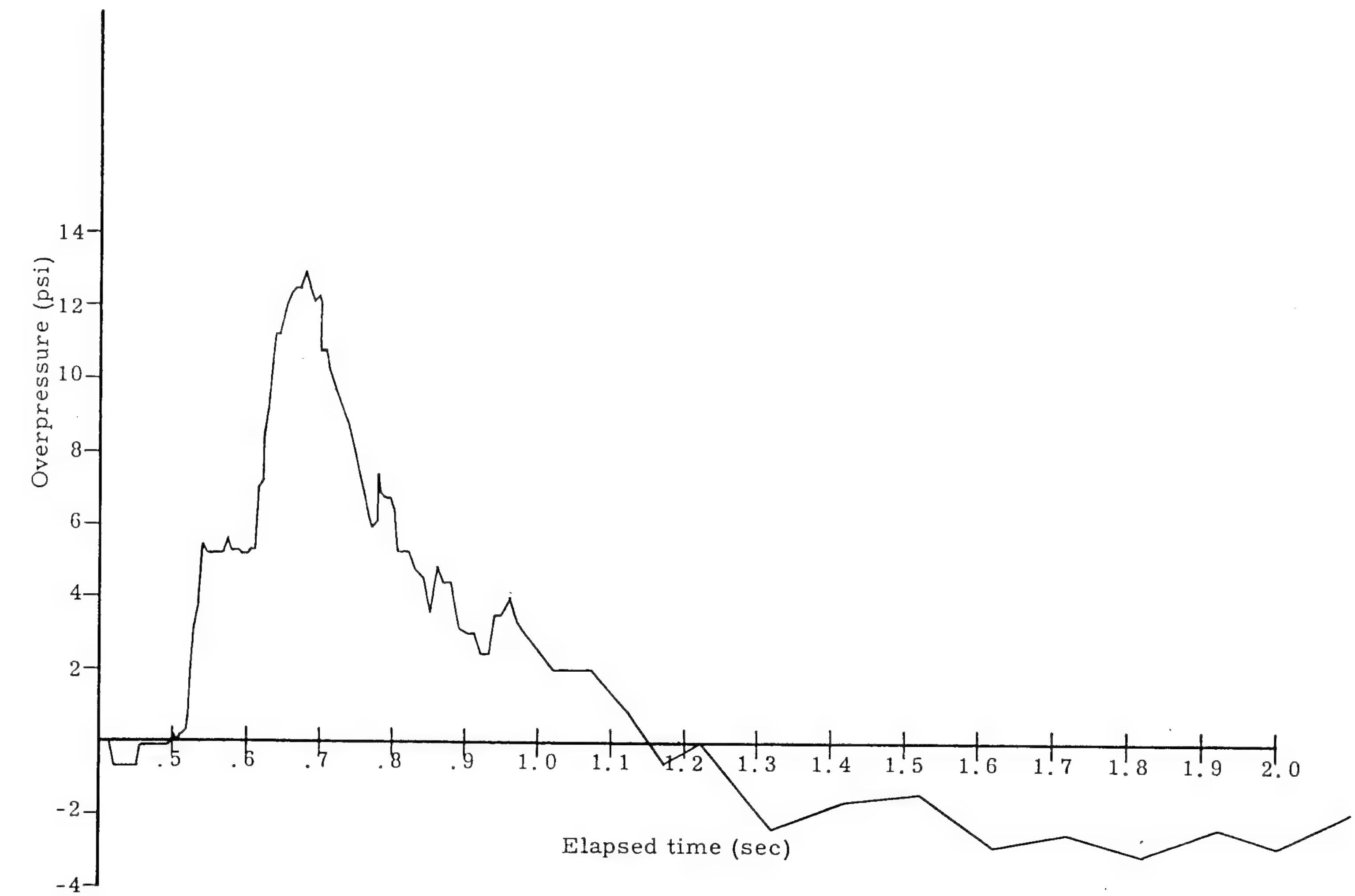


Fig. 48. -- Shot Charlie (A2S) (ground baffle) (distance from ground zero: 1,246 ft)

[redacted]

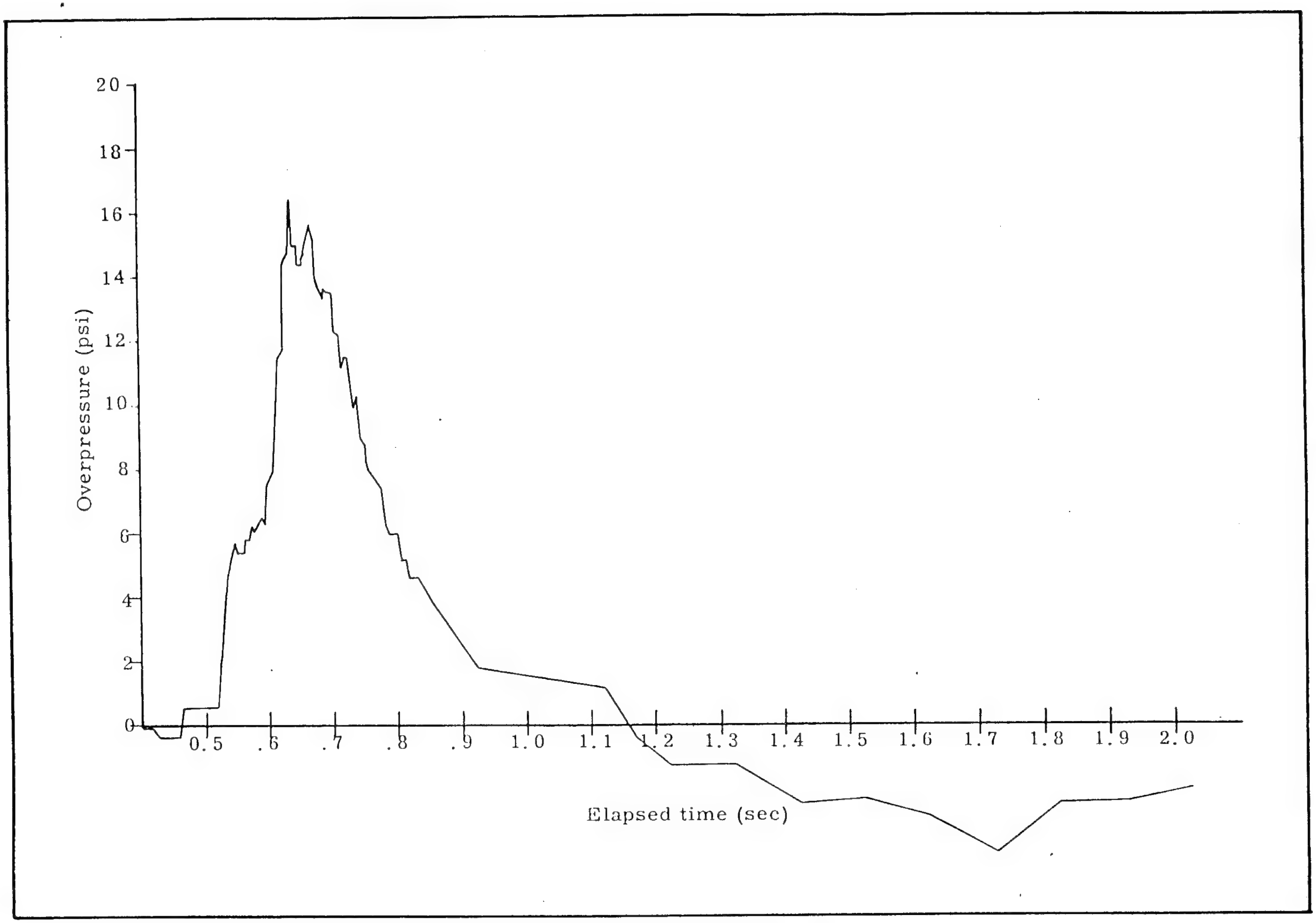


Fig. 49. -- Shot Charlie (DS) (ground baffle) (distance from ground zero: 1,245 ft)

[redacted]

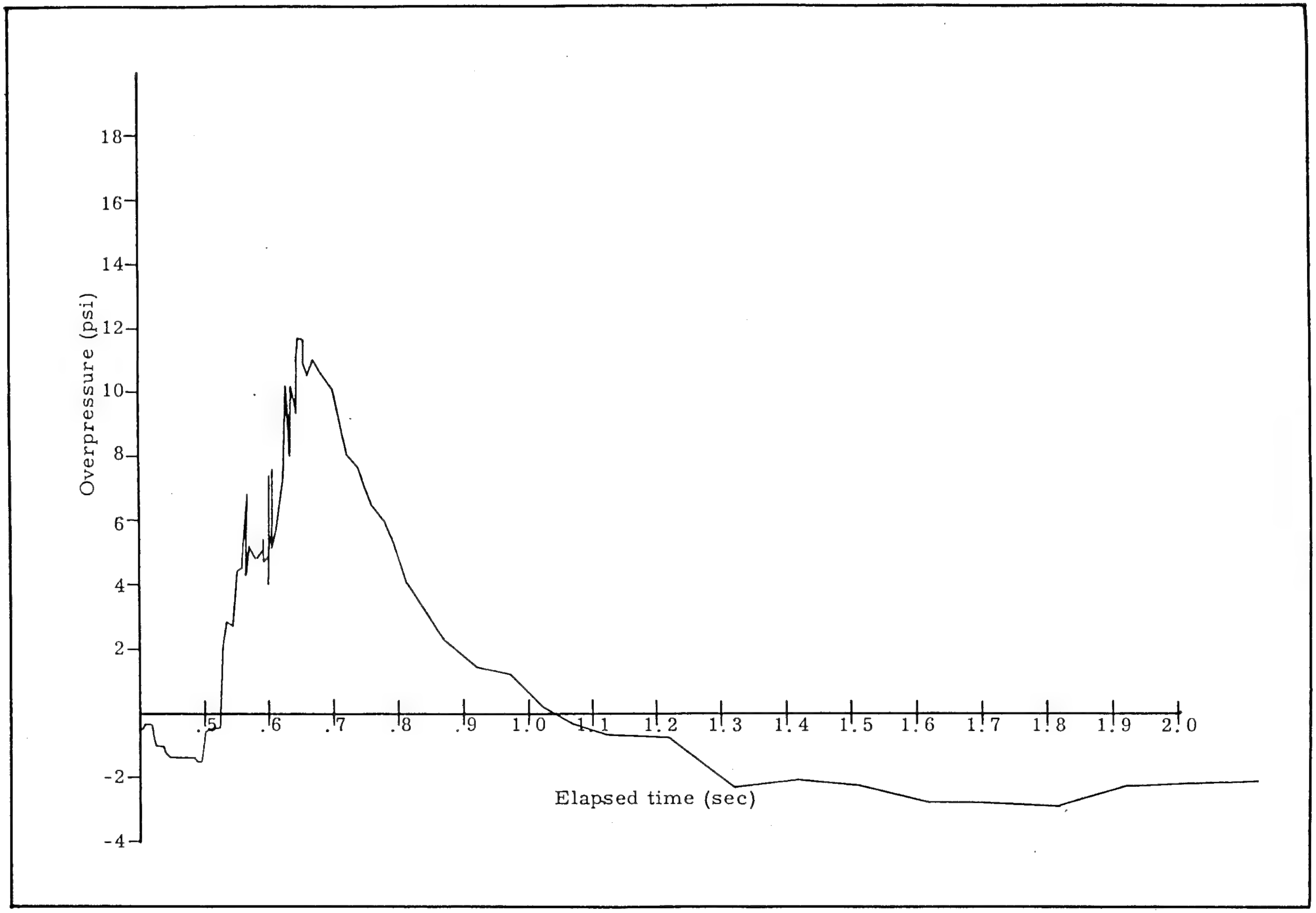


Fig. 50. -- Shot Charlie (D15L) (gauge 15 ft above ground) (distance from ground zero: 1, 245 ft)

[redacted]

[redacted]

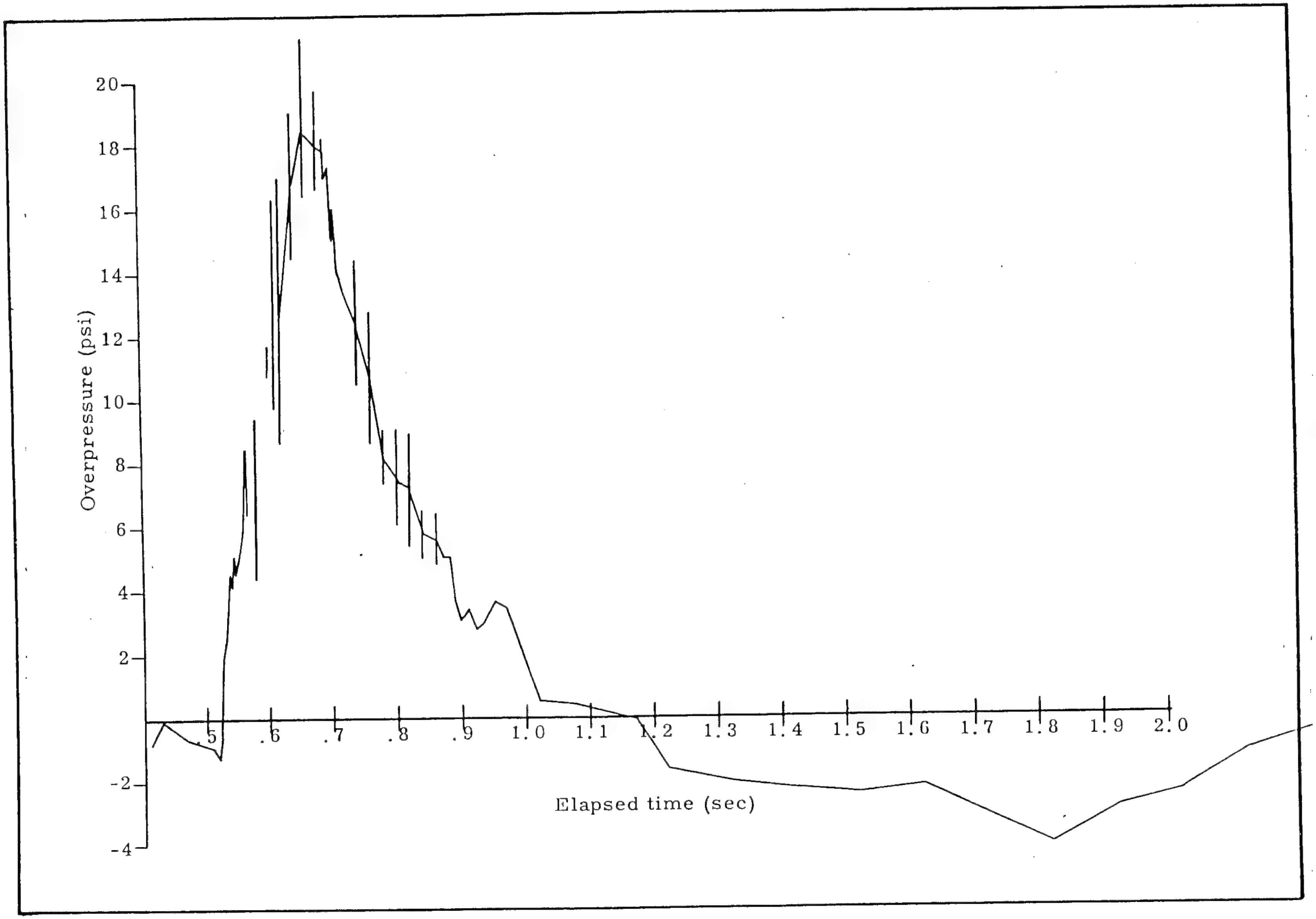


Fig. 51. -- Shot Charlie (D15R) (gauge 15 ft above ground) (distance from ground zero: 1,245 ft)

[redacted]

[redacted]

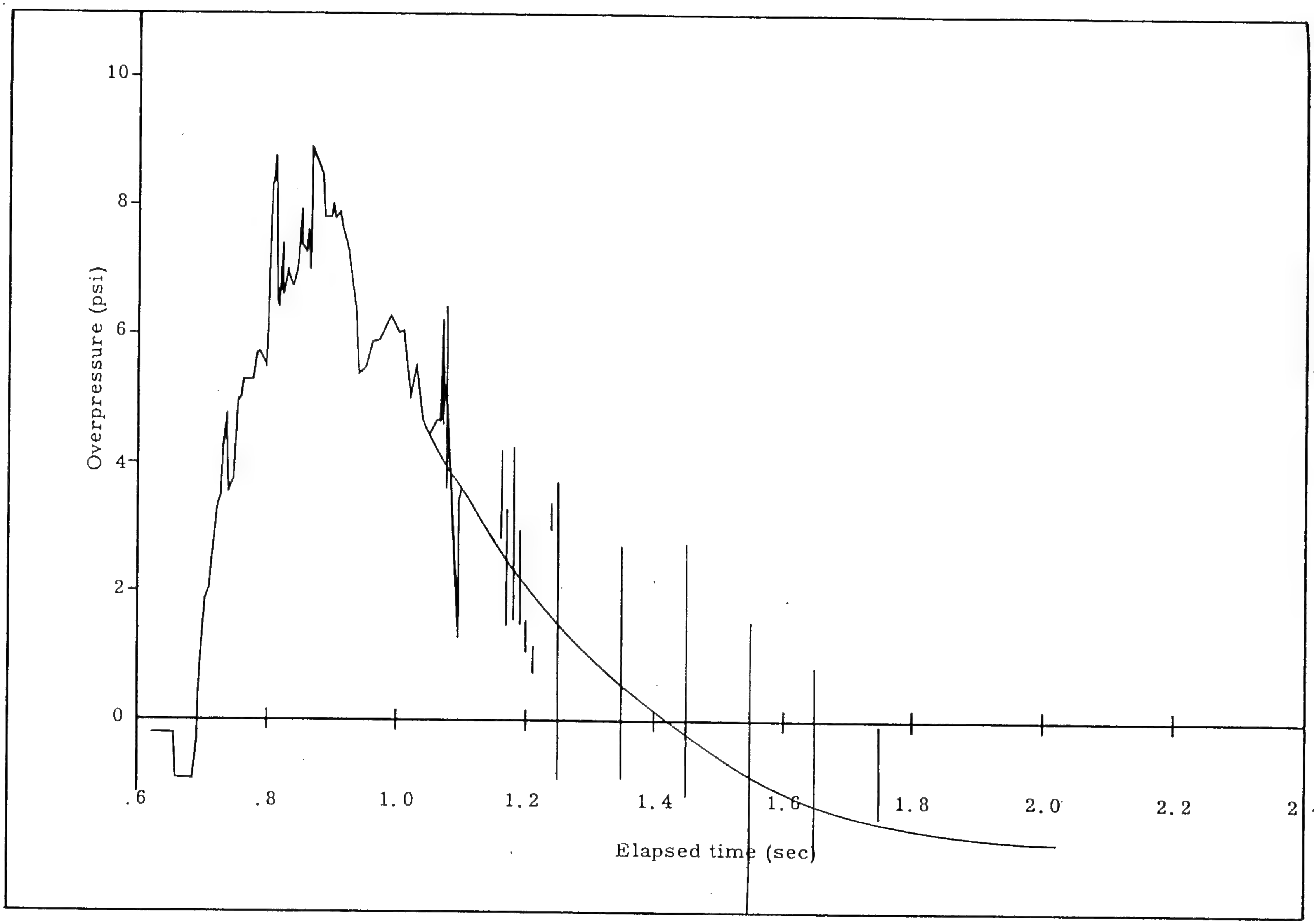


Fig. 52. -- Shot Charlie (ES) (ground baffle) (distance from ground zero: 1,673 ft)

[redacted]

[redacted]

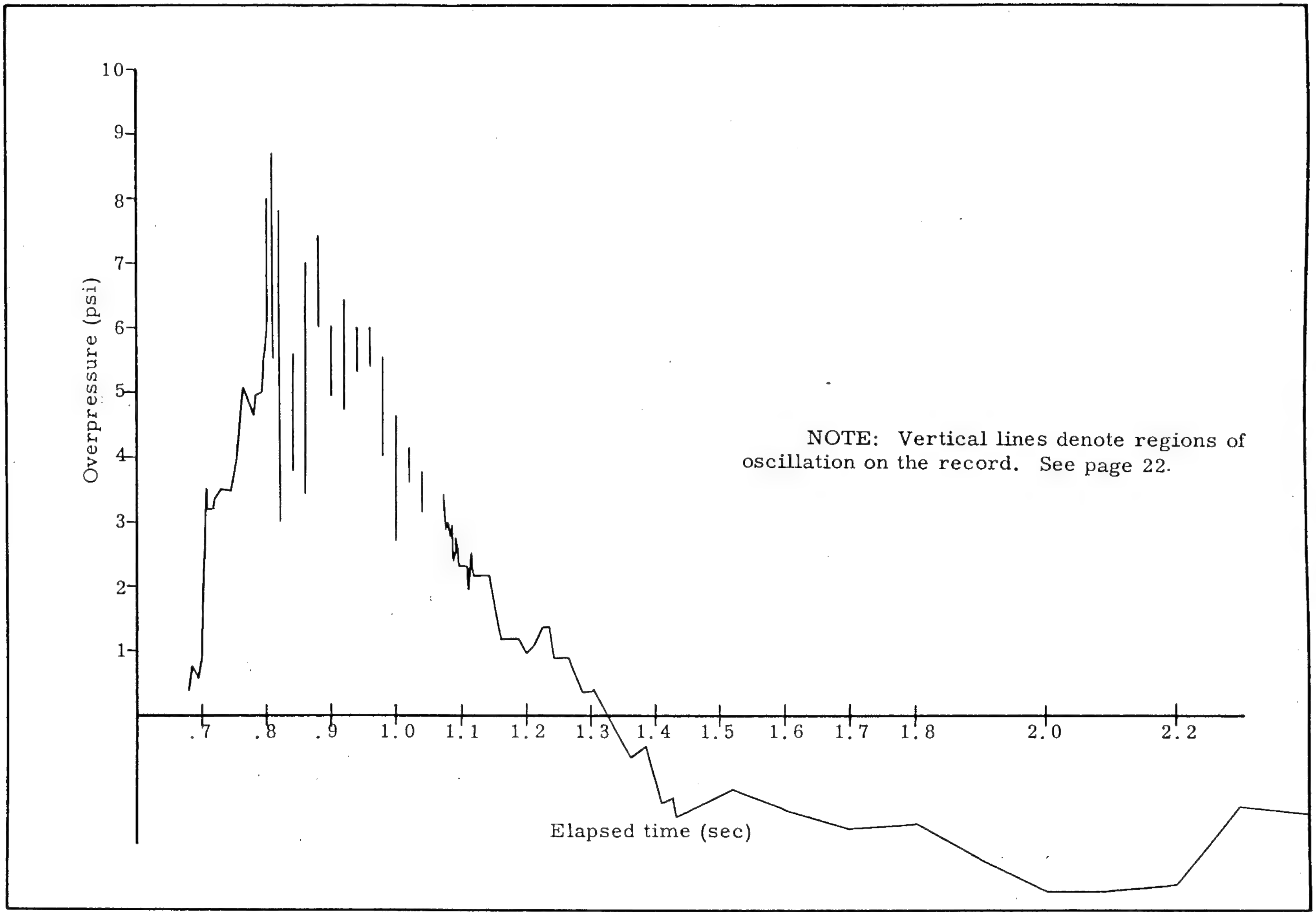


Fig. 53. -- Shot Charlie (E15L) (gauge 15 ft above ground) (distance from ground zero: 1,673 ft)

[redacted]

[redacted]

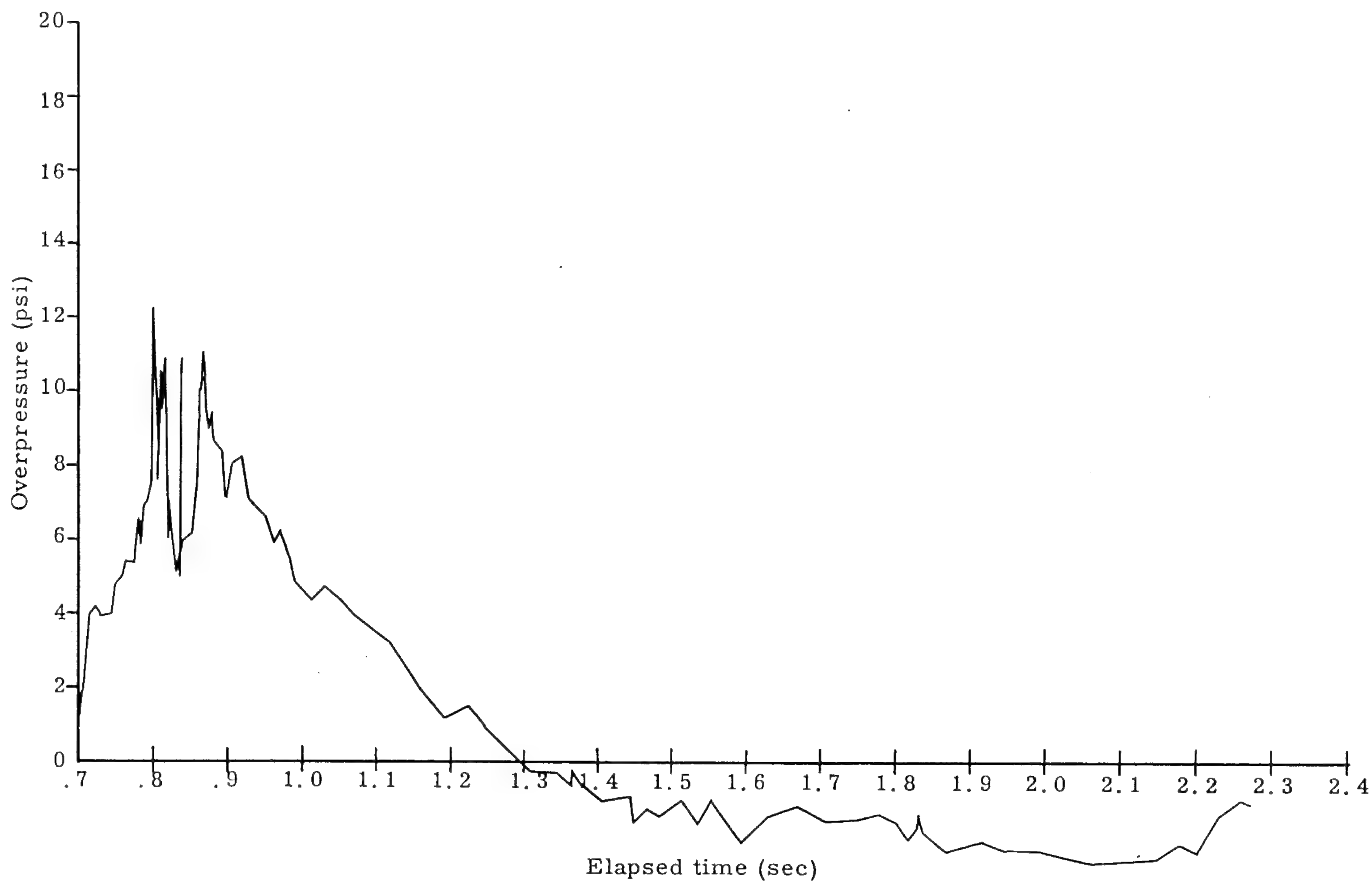


Fig. 54. -- Shot Charlie (E15R) (gauge 15 ft above ground) (distance from ground zero: 1,673 ft)

[redacted]

[redacted]

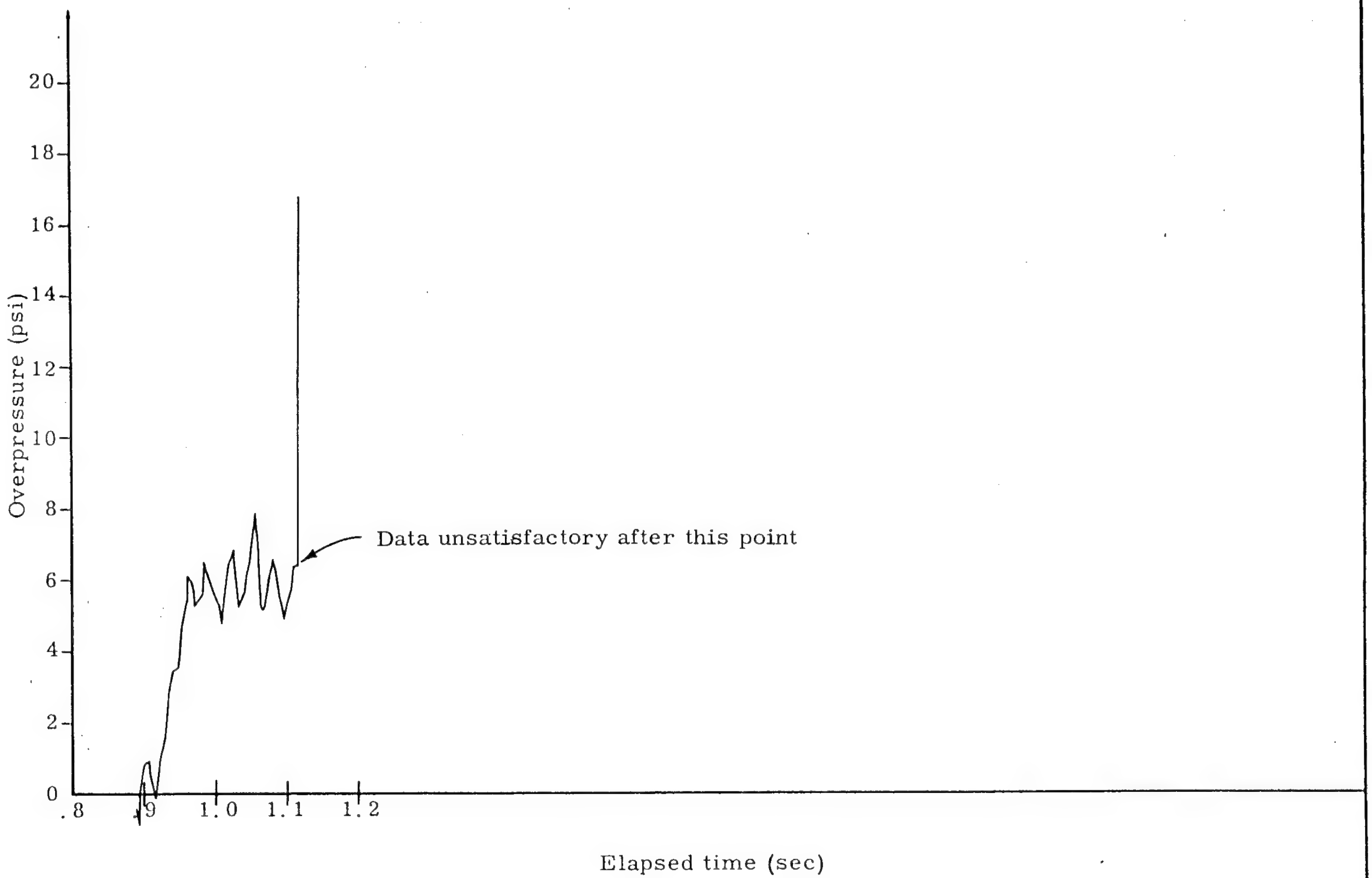
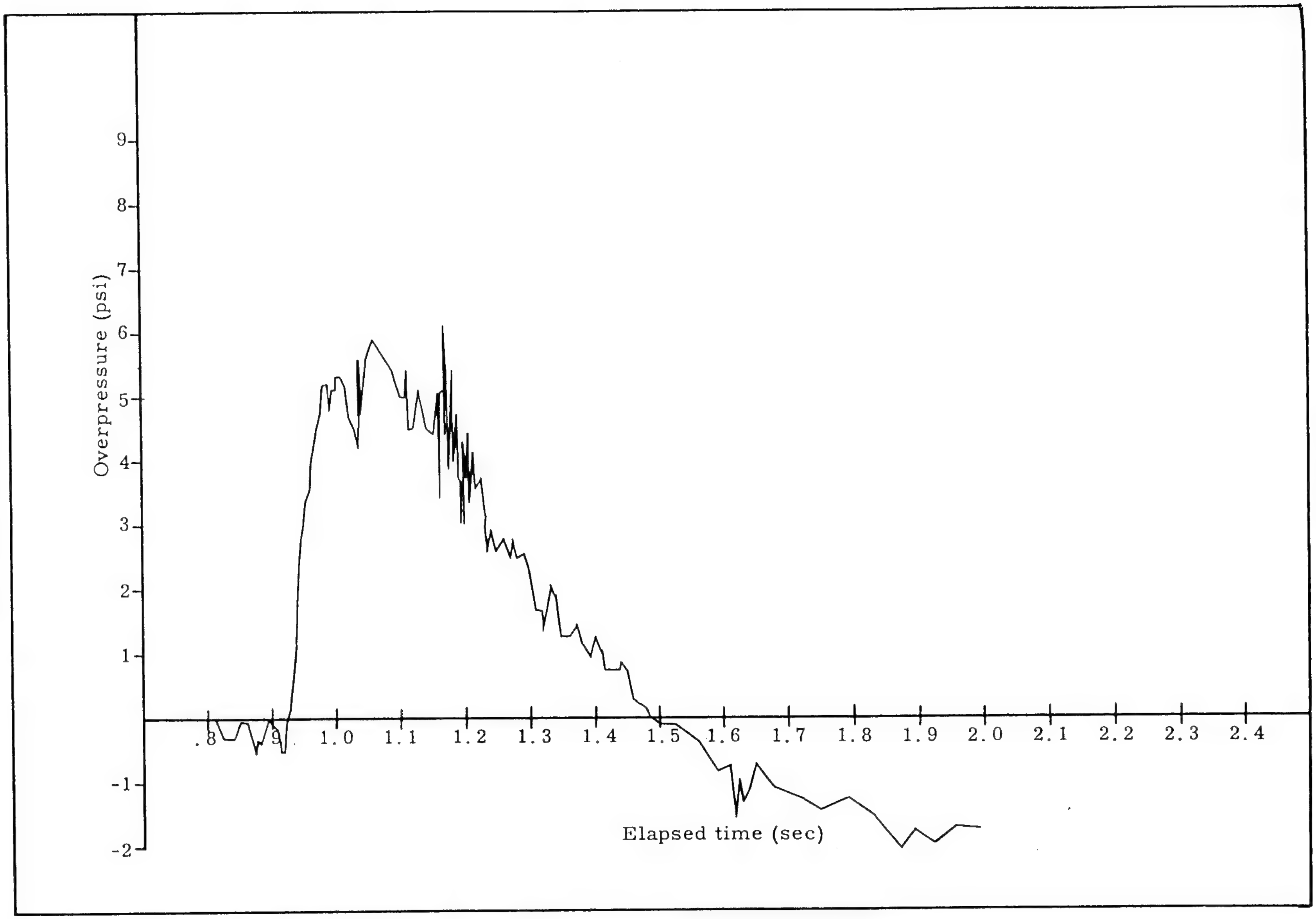


Fig. 55. -- Shot Charlie (FS) (ground baffle) (distance from ground zero: 2, 138 ft)

[redacted]

[redacted]



[redacted]

Fig. 56. -- Shot Charlie (F15R) (gauge 15 ft above ground) (distance from ground zero: 2, 138 ft)

[redacted]

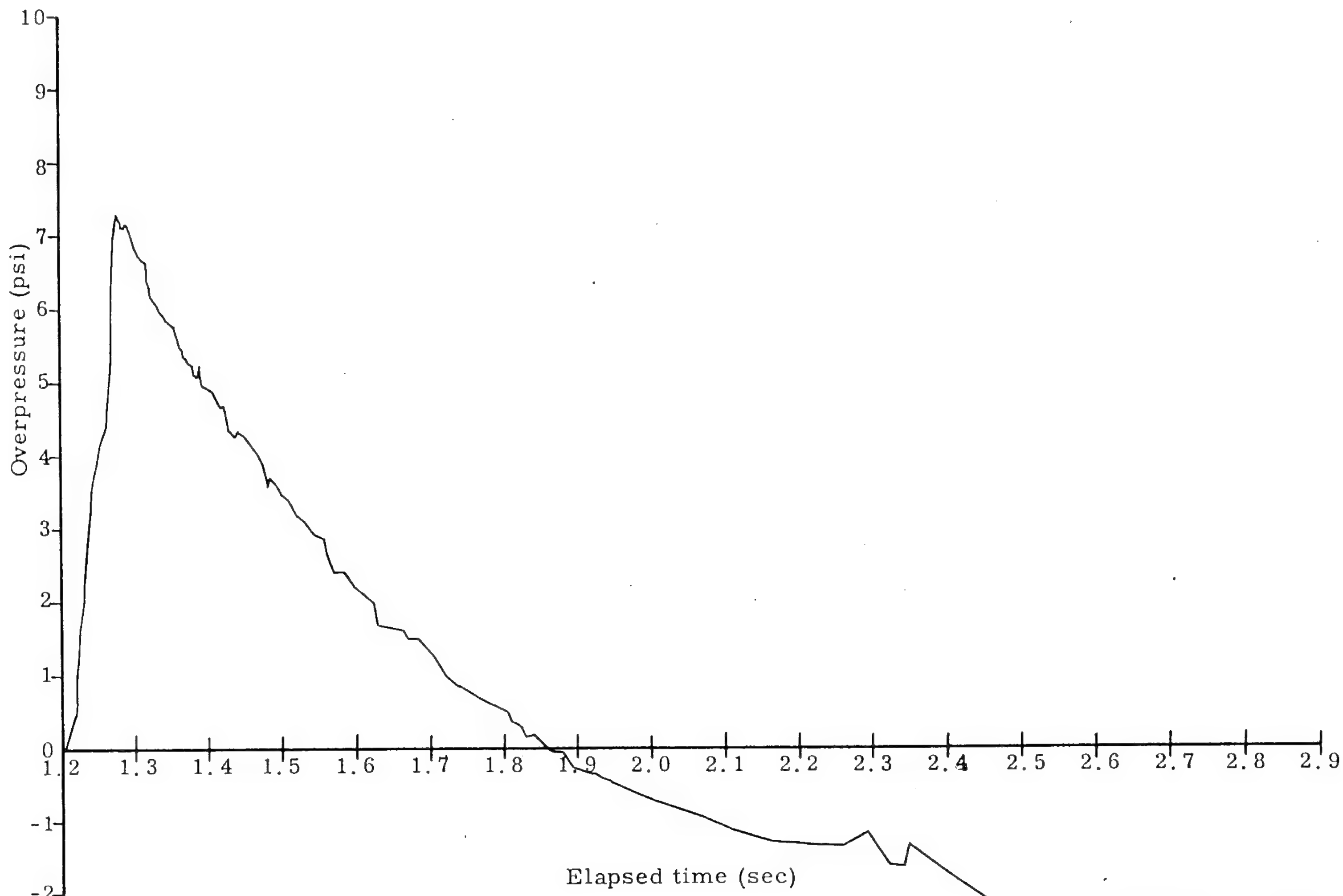


Fig. 57. -- Shot Charlie (GS) (ground baffle) (distance from ground zero: 2,495 ft)

[redacted]

[redacted]

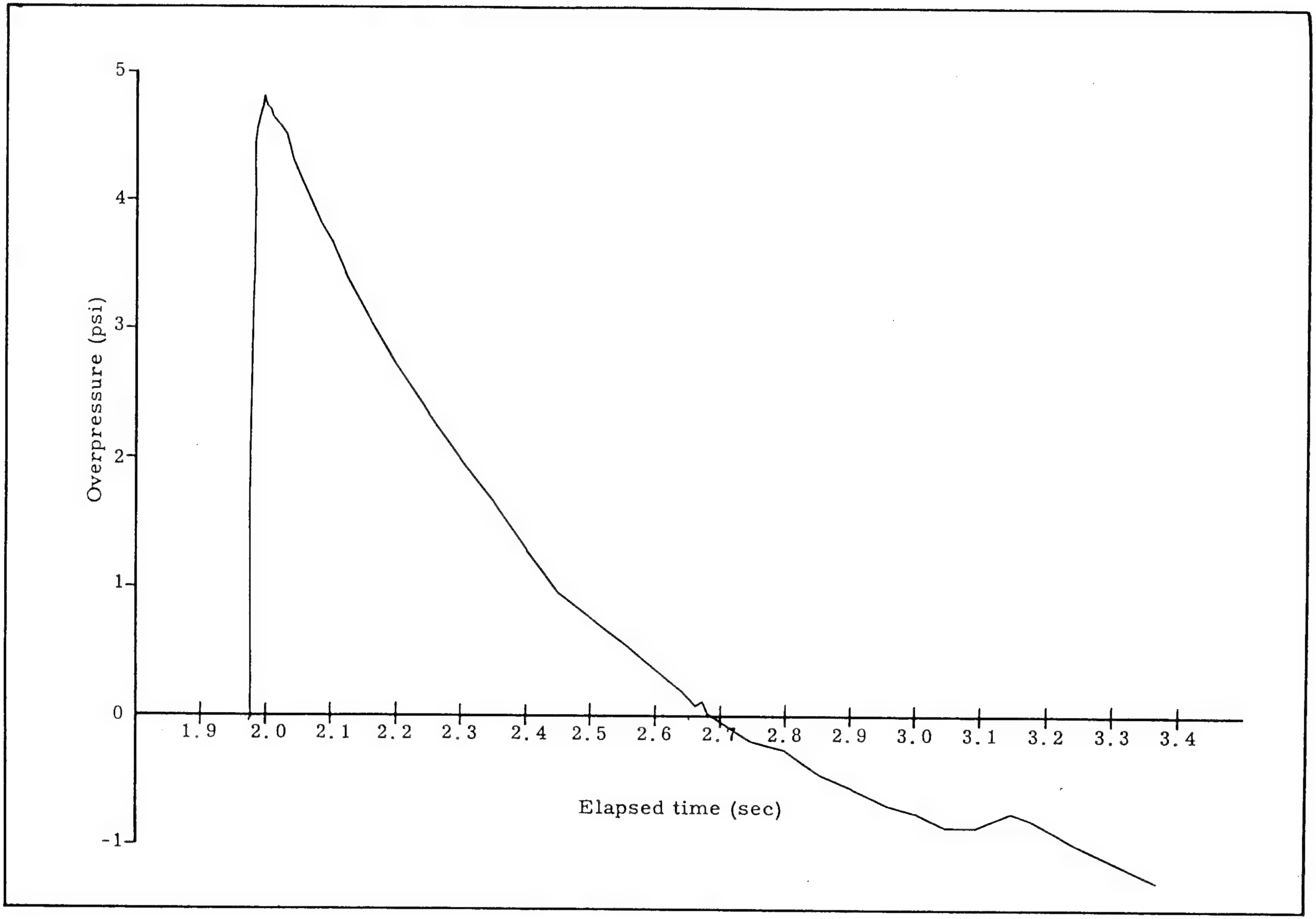


Fig. 58. -- Shot Charlie (HS) (ground baffle) (distance from ground zero: 3,505 ft)

[redacted]

[redacted]

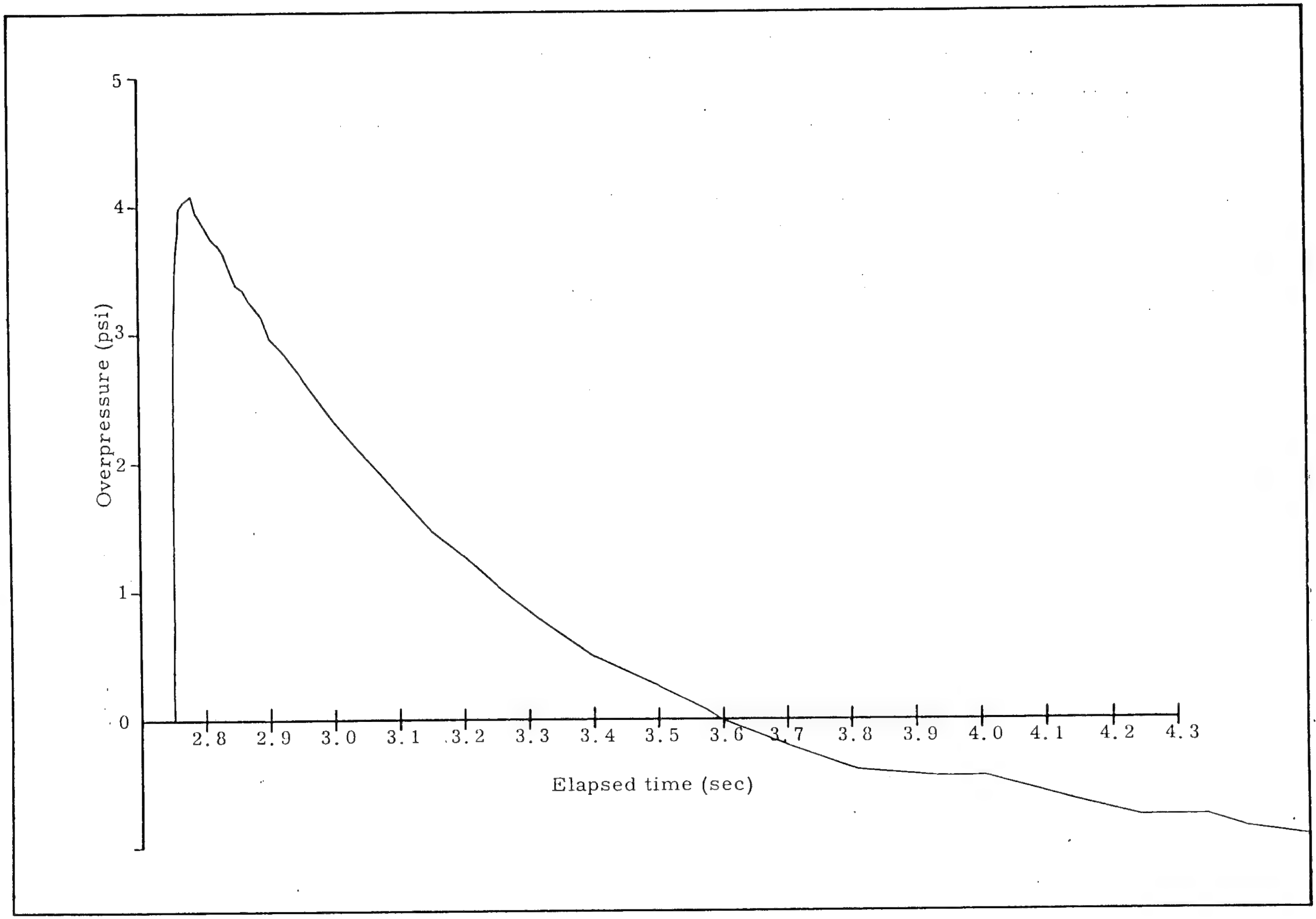


Fig. 59. -- Shot Charlie (IS) (ground baffle) (distance from ground zero: 4, 520 ft)

[redacted]

[redacted]

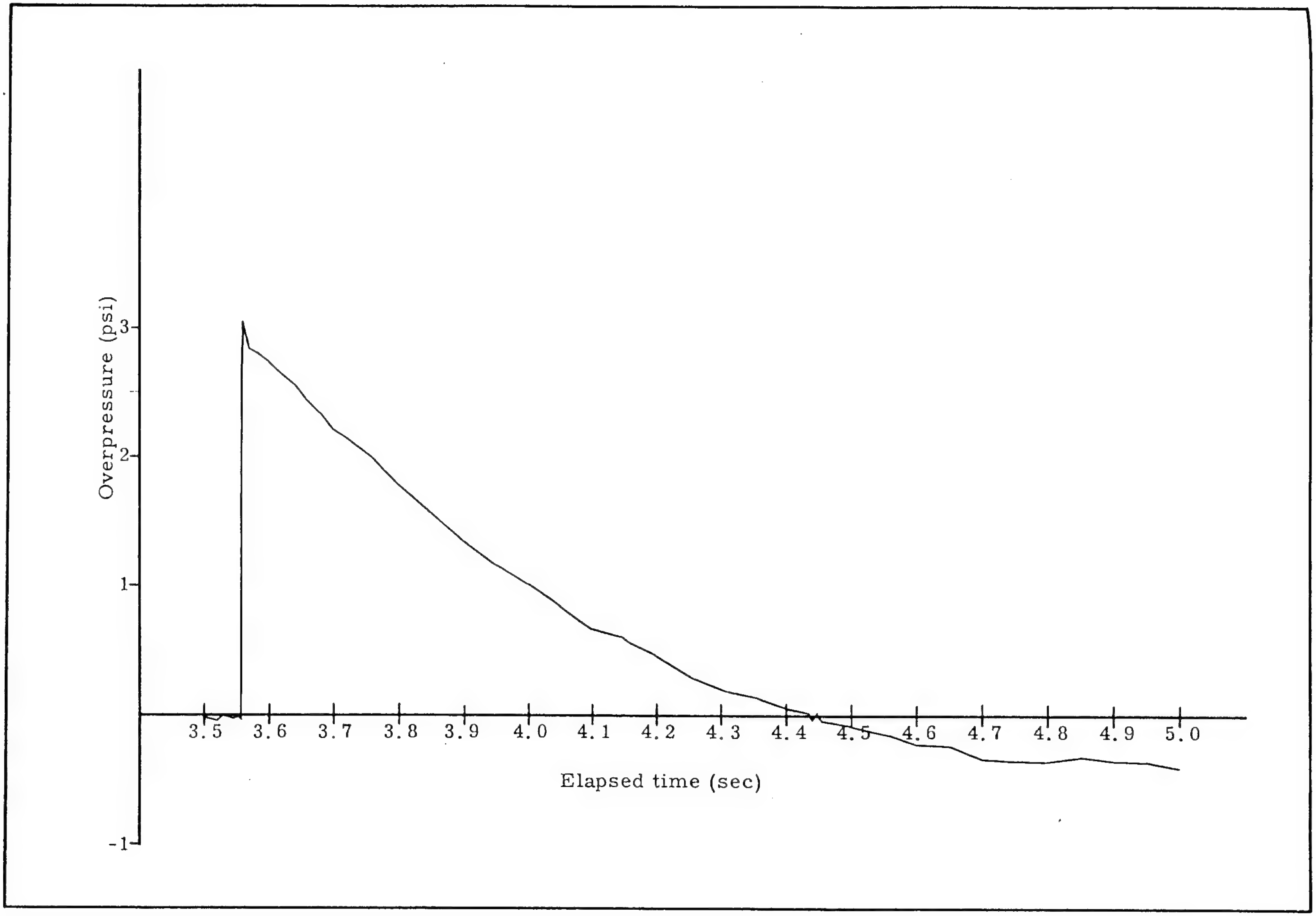


Fig. 60. -- Shot Charlie (JS) (ground baffle) (distance from ground zero: 5,520 ft)

[redacted]

[redacted]

Pressure-Time Data
Shot Dog

[redacted]

[redacted]

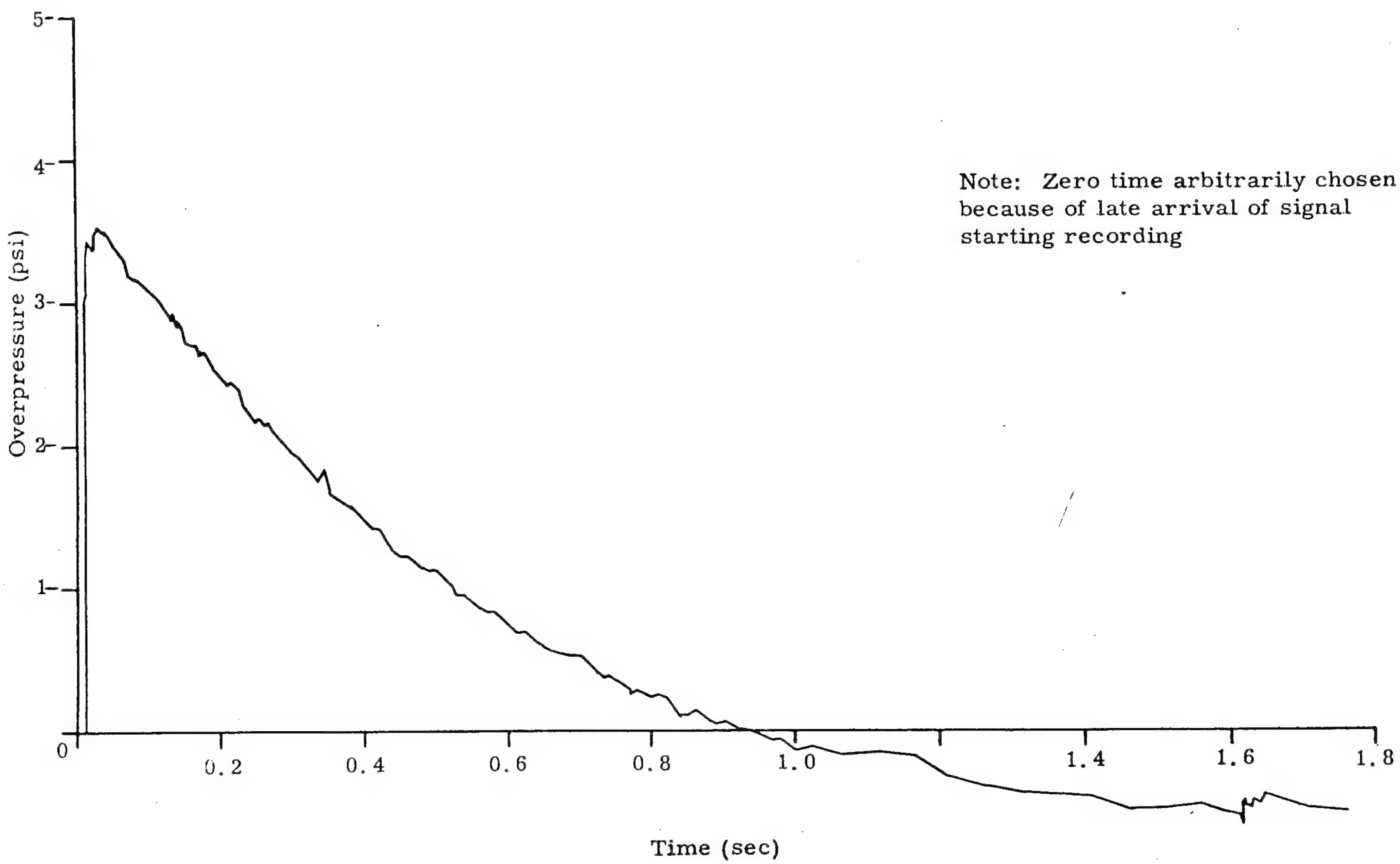


Fig. 61. -- Shot Dog (JS) (ground baffle) (distance from ground zero: 5,400 ft)

[redacted]

[redacted]

Pressure-Time Data
Shot Easy

[redacted]

[redacted]

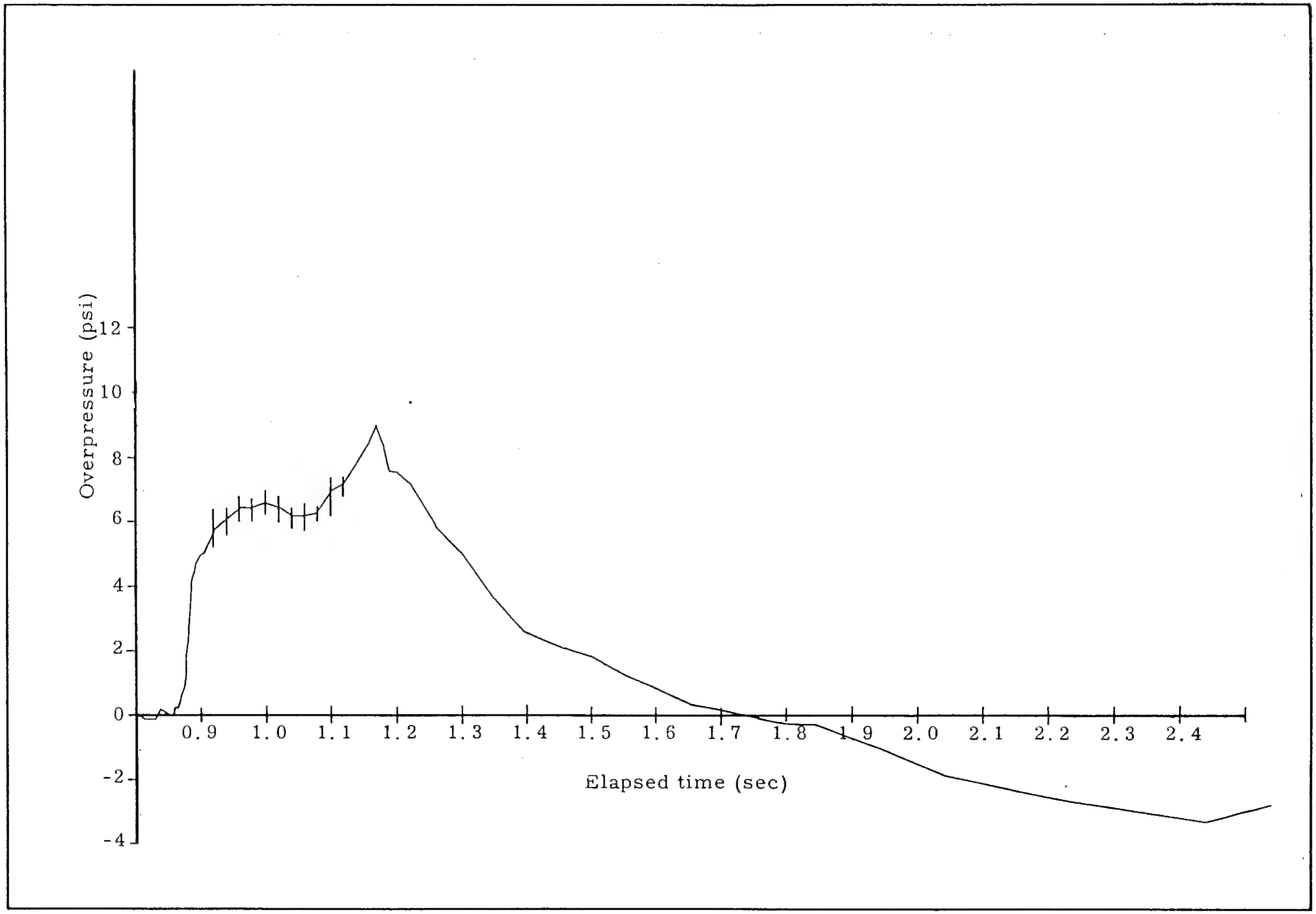


Fig. 62. -- Shot Easy (E2S) (ground baffle) (distance from ground zero: 2,031 ft)

[redacted]

[redacted]

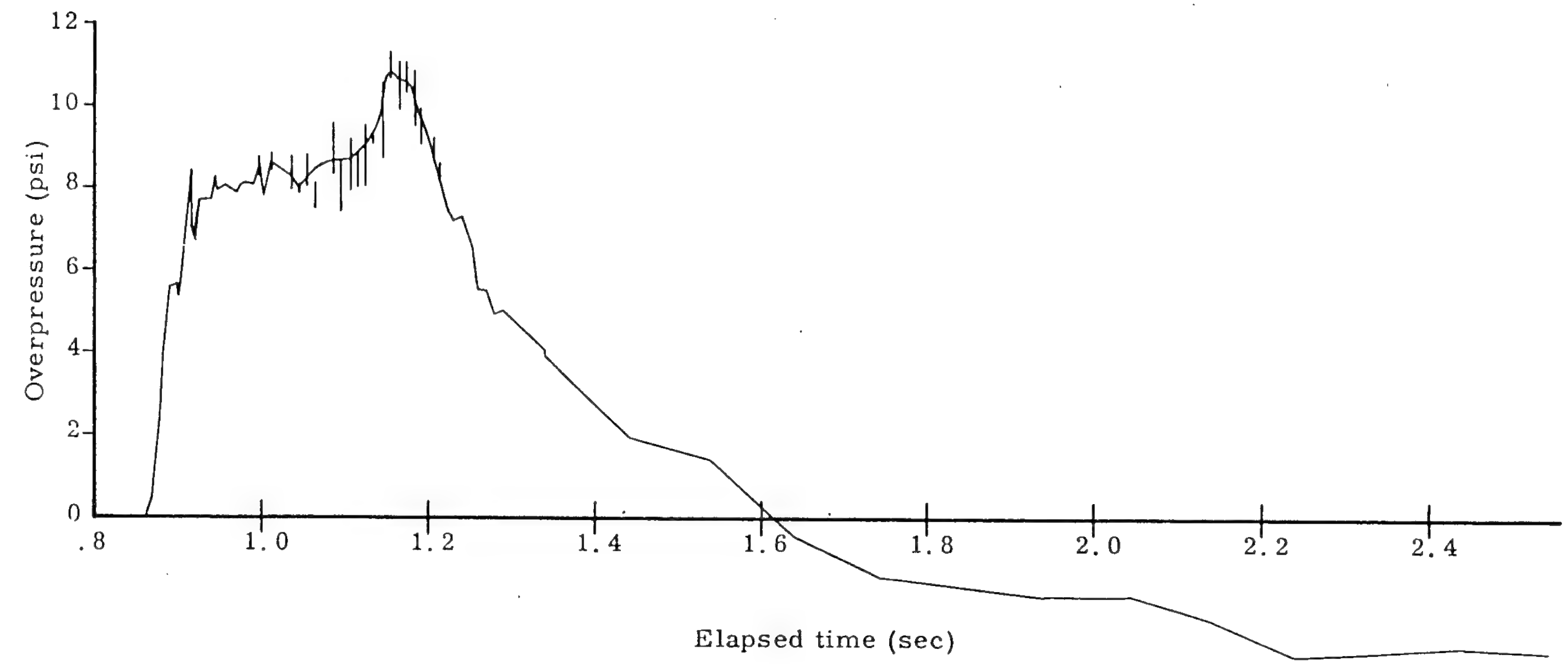


Fig. 63. -- Shot Easy (B2PO) (ground baffle) (distance from ground zero: 2, 031 ft)

[redacted]

[redacted]

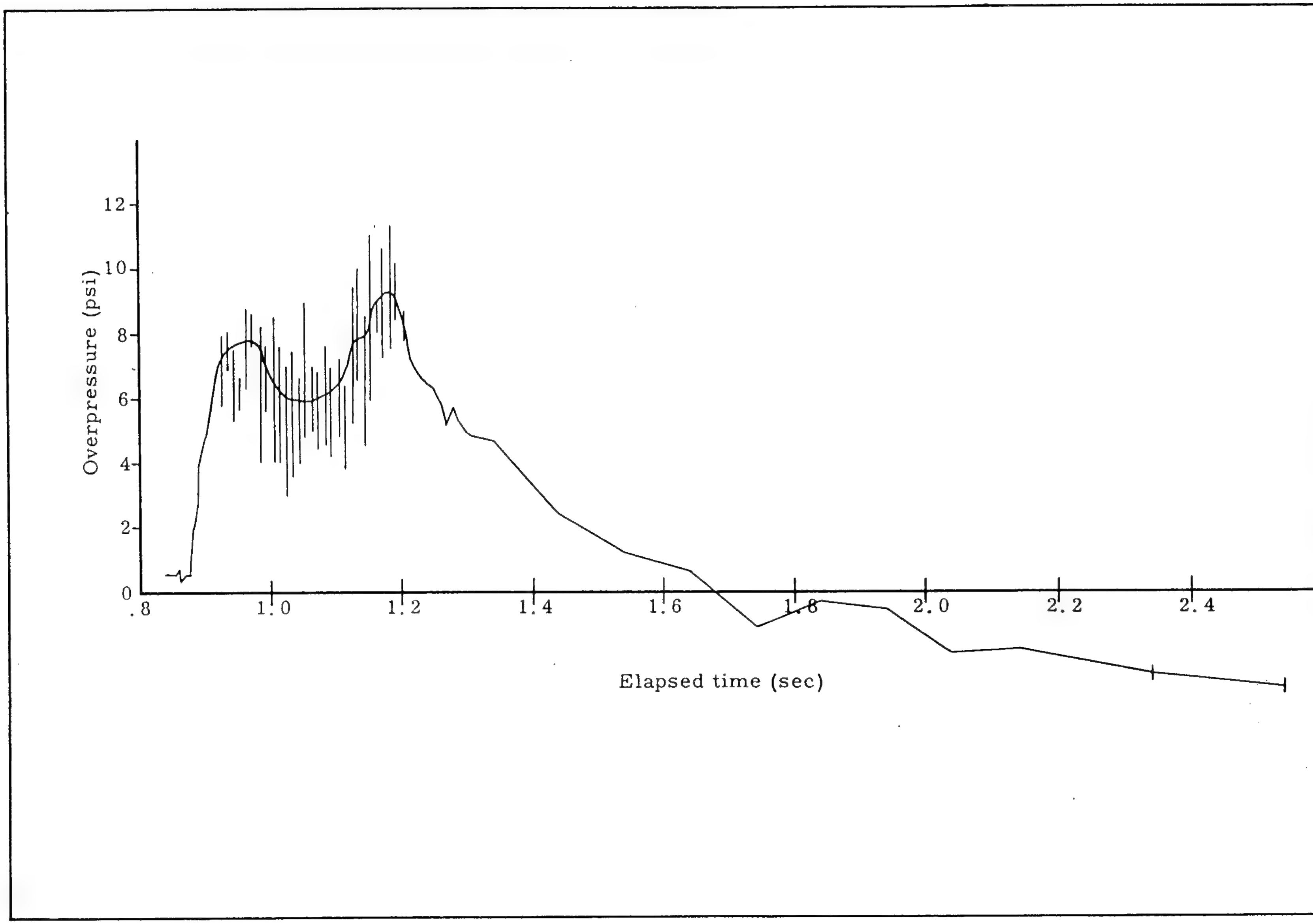


Fig. 64. -- Shot Easy (E2P5) (gauge 5 ft above ground) (distance from ground zero: 2, 031 ft)

[redacted]

[redacted]

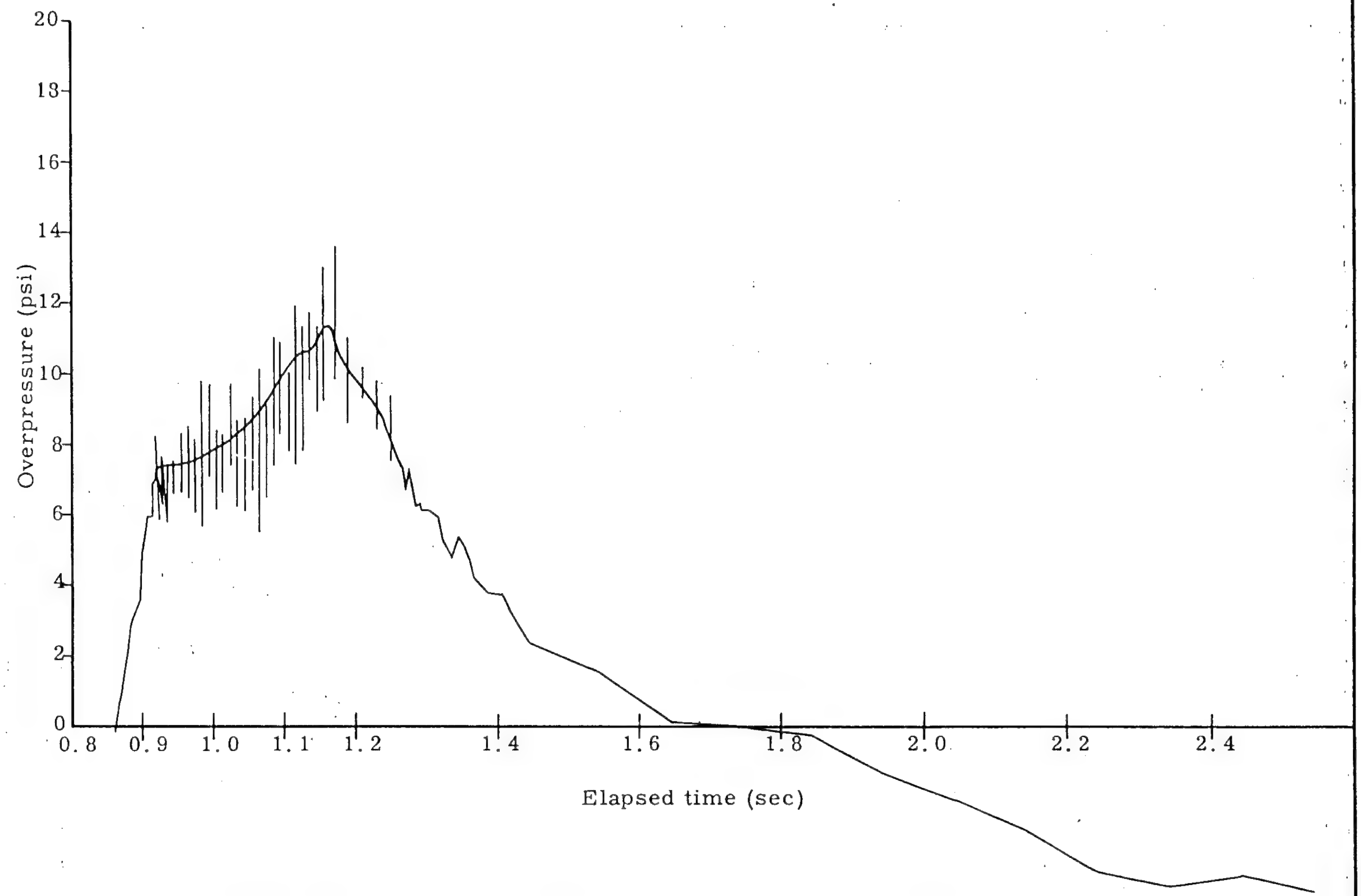


Fig. 65. -- Shot Easy (B2P10) (gauge 10 ft above ground) (distance from ground zero: 2,031 ft)

[redacted]

[redacted]

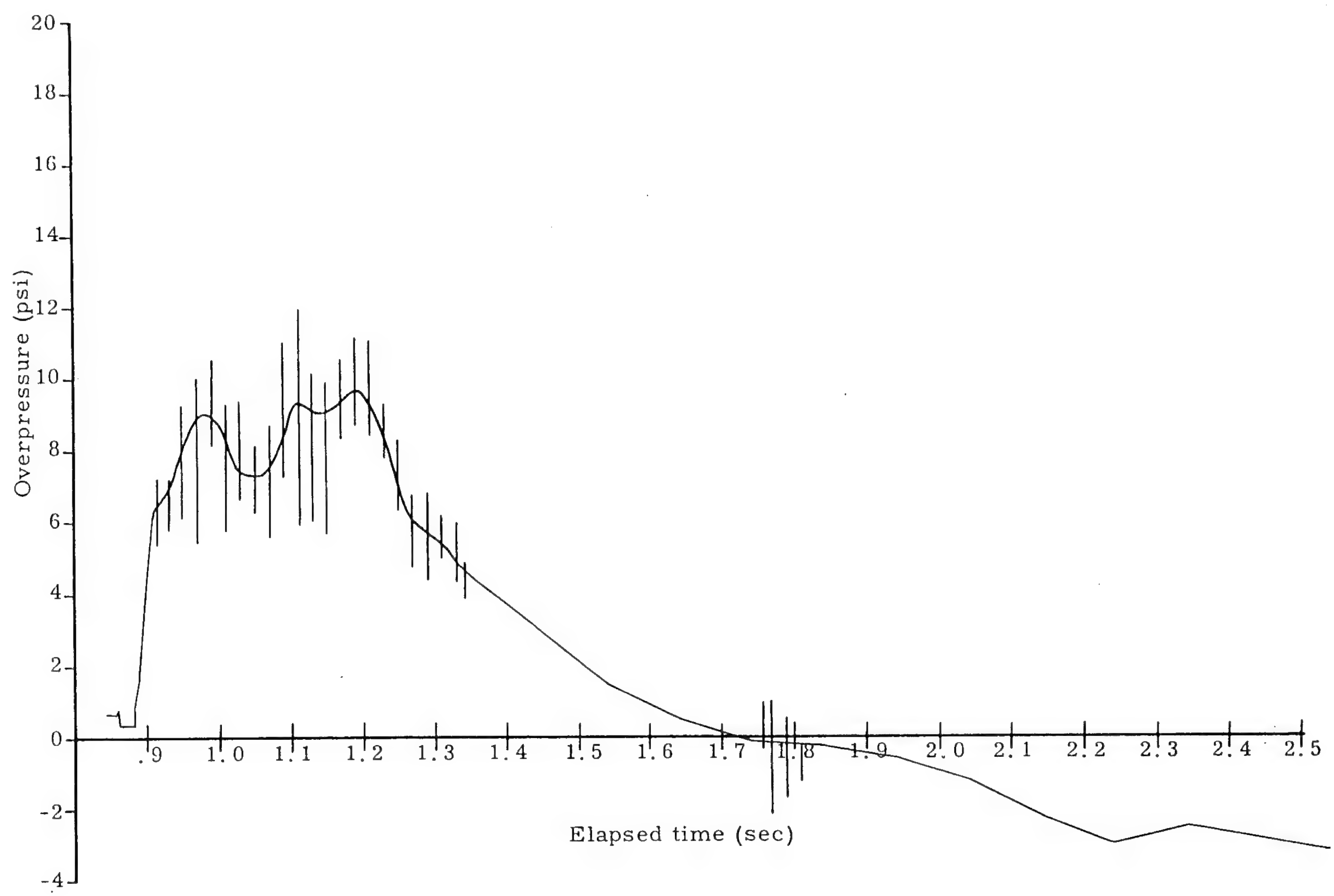


Fig. 66. -- Shot Easy (B2P25) (gauge 25 ft above ground) (distance from ground zero: 2,031 ft)

[redacted]

[redacted]

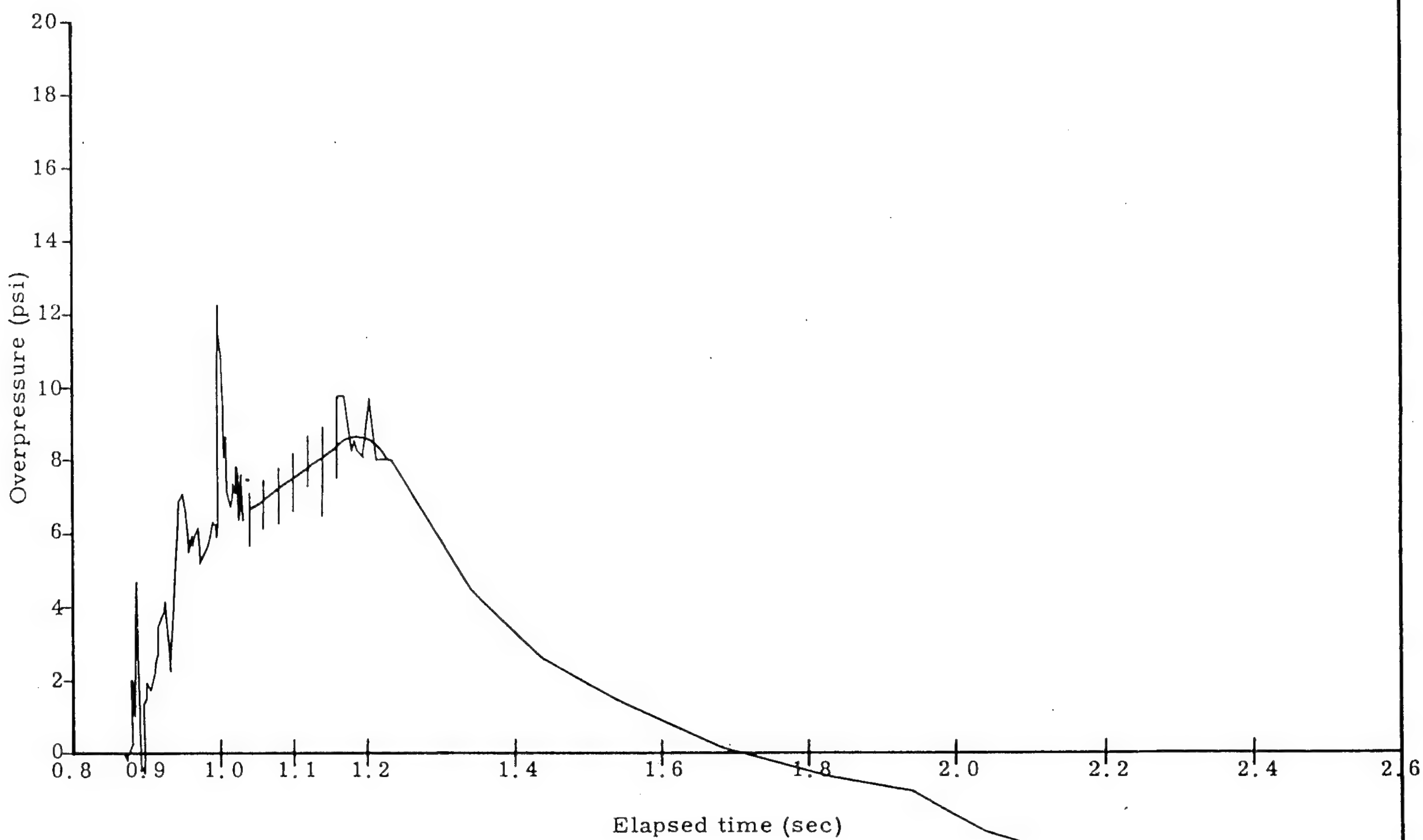


Fig. 67. -- Shot Easy (E2P50) (gauge 50 ft above ground) (distance from ground zero: 2,031 ft)

[redacted]

[redacted]

[redacted]

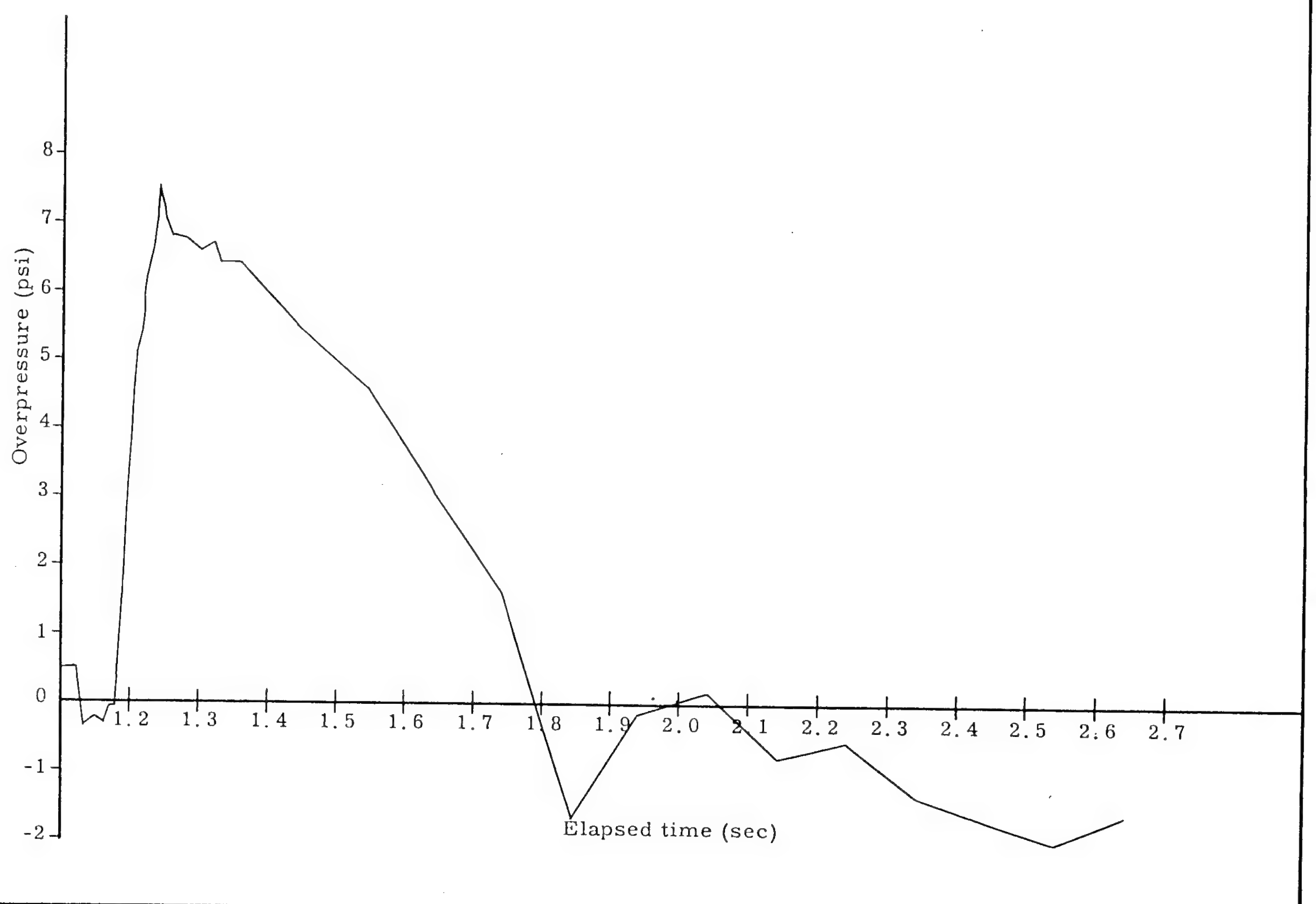


Fig. 68. -- Shot Easy (CS) (ground baffle) (distance from ground zero: 2,505 ft)

[redacted]

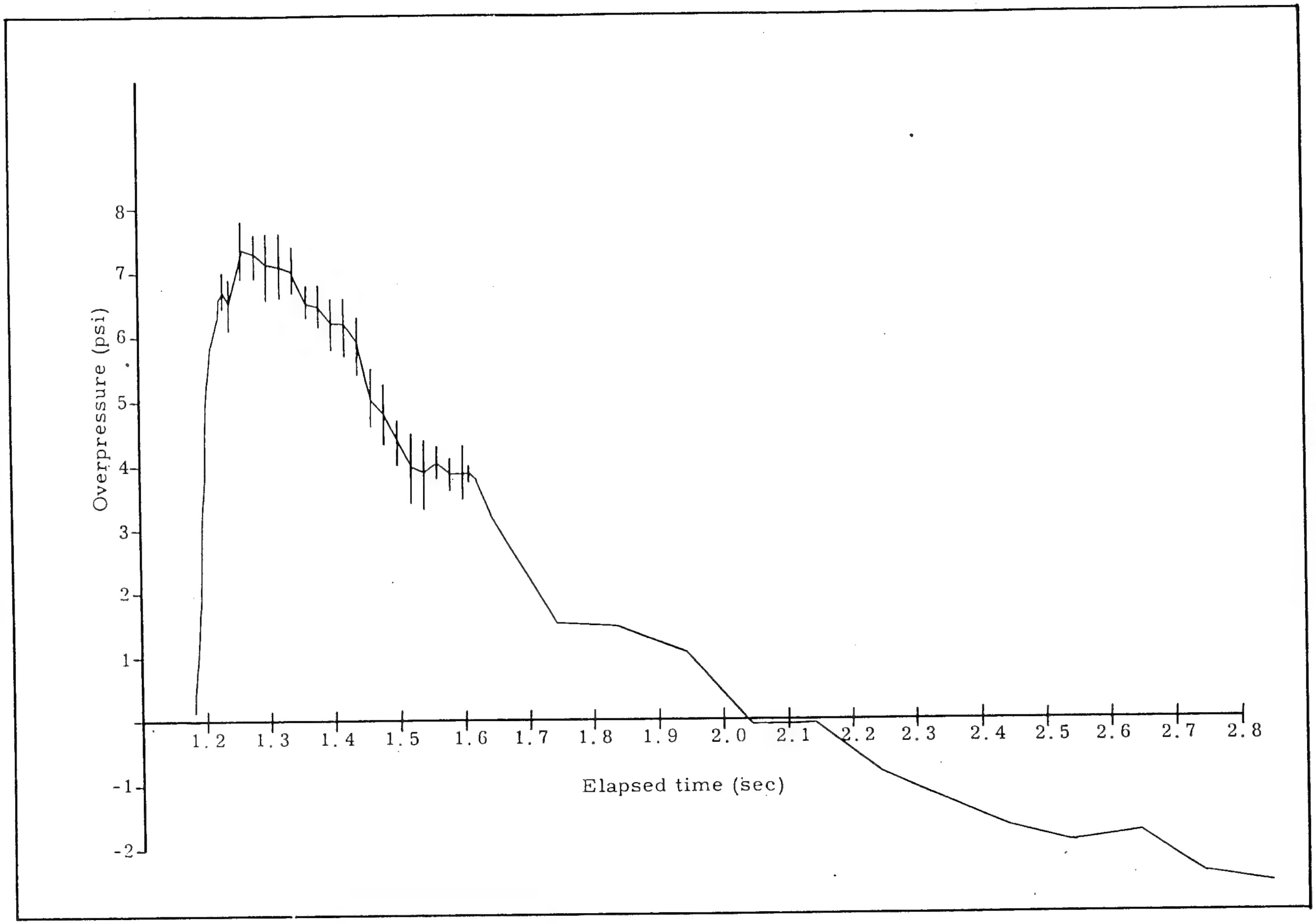


Fig. 69. -- Shot Easy (C15R) (gauge 15 ft above ground) (distance from ground zero: 2, 505 ft)

[redacted]

[redacted]

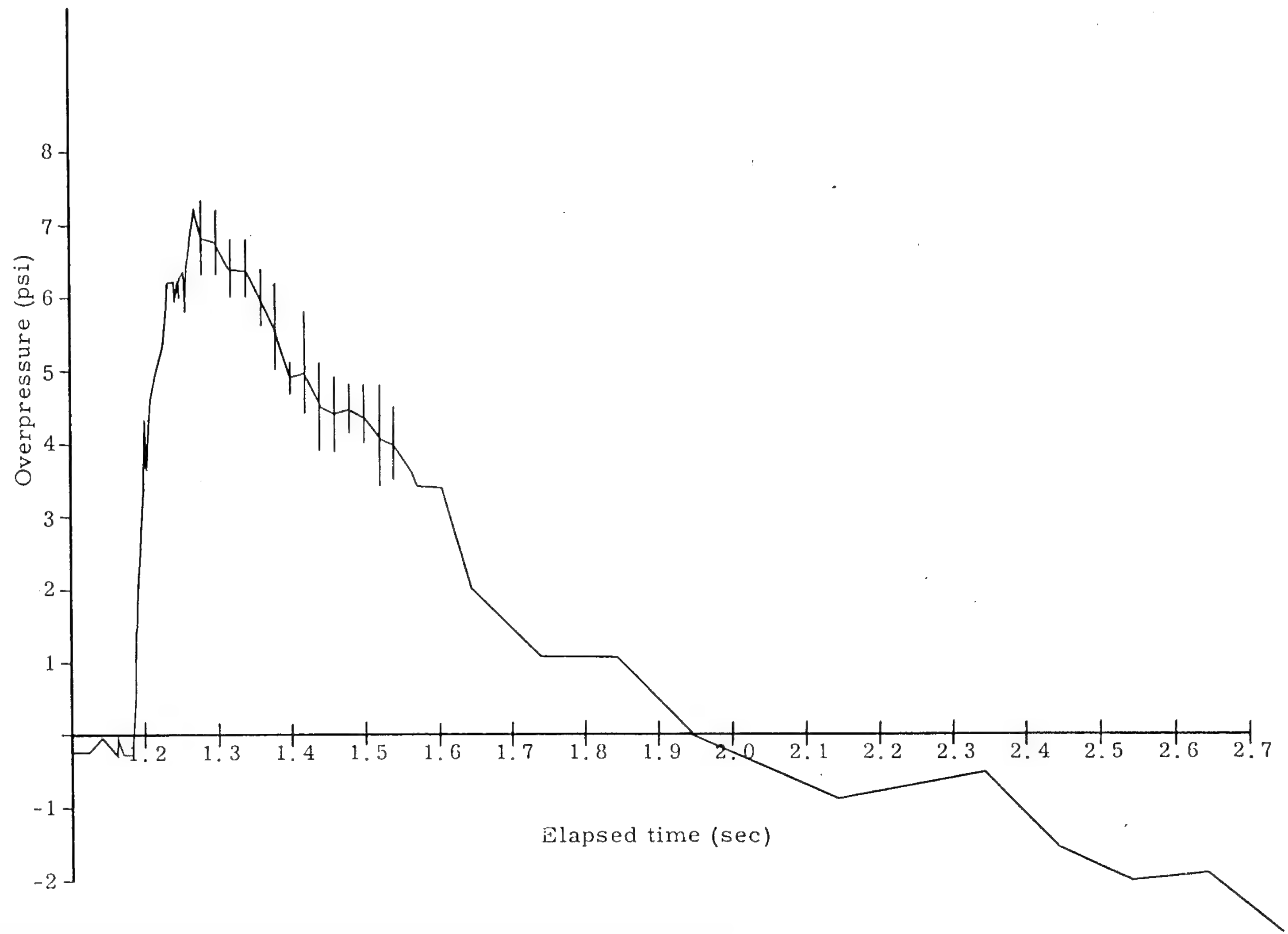


Fig. 70. -- Shot Easy (C15L) (gauge 15 ft above ground) (distance from ground zero: 2,505 ft)

[redacted]

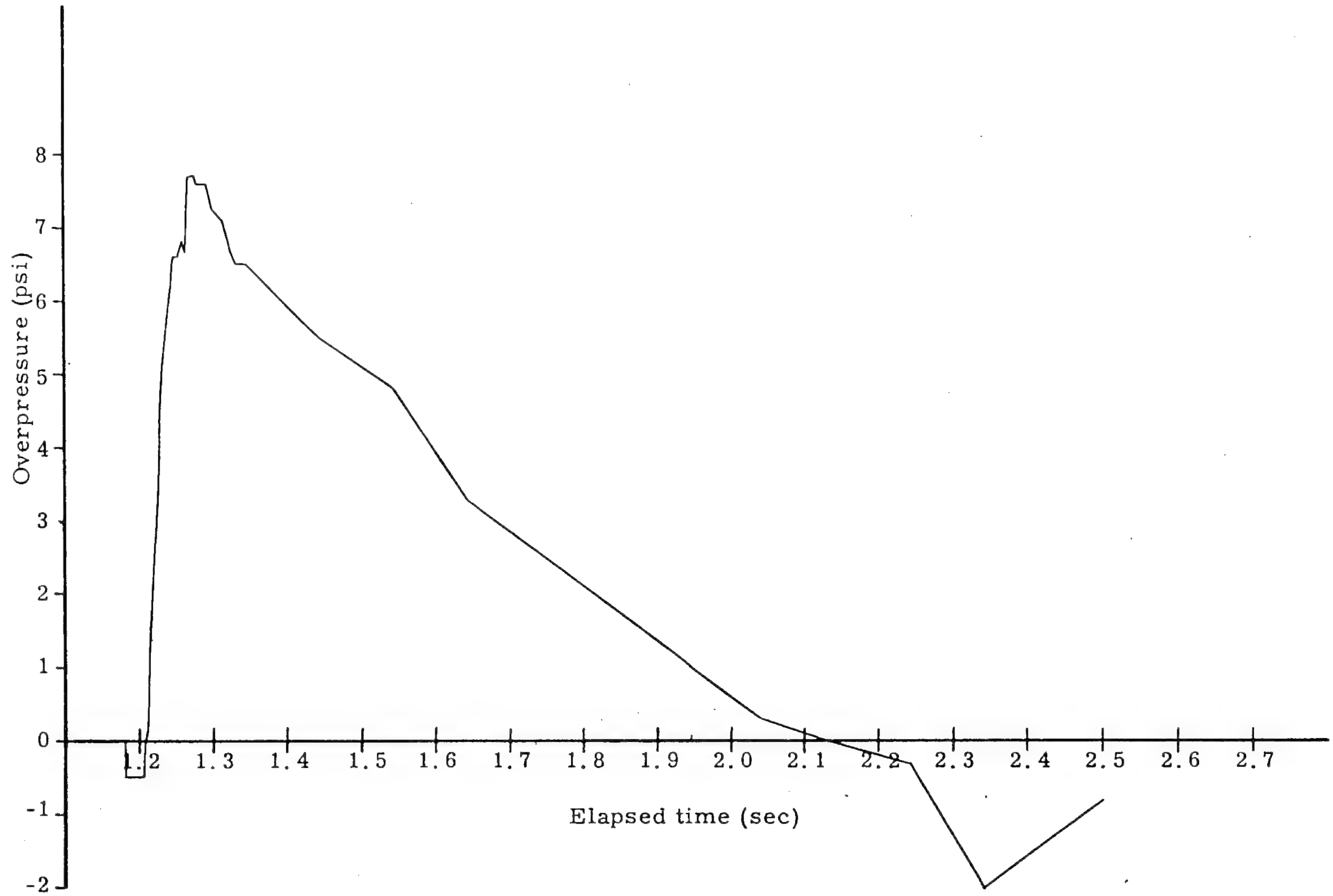


Fig. 71. -- Shot Easy (B3S) (ground baffle) (distance from ground zero: 2,541 ft)

[redacted]

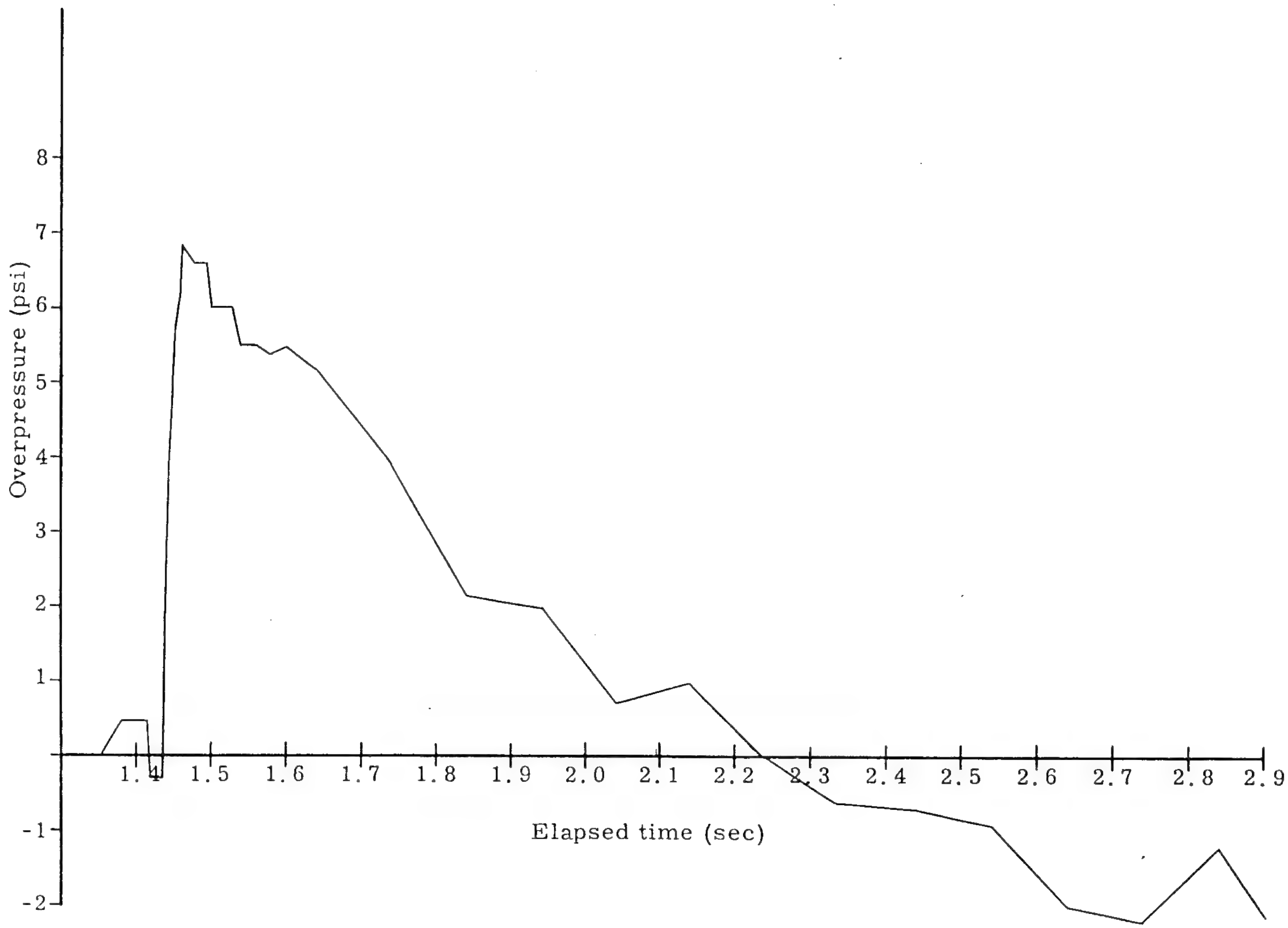


Fig. 72. -- Shot Easy (A3S) (ground baffle) (distance from ground zero: 2,873 ft)

[redacted]

[redacted]

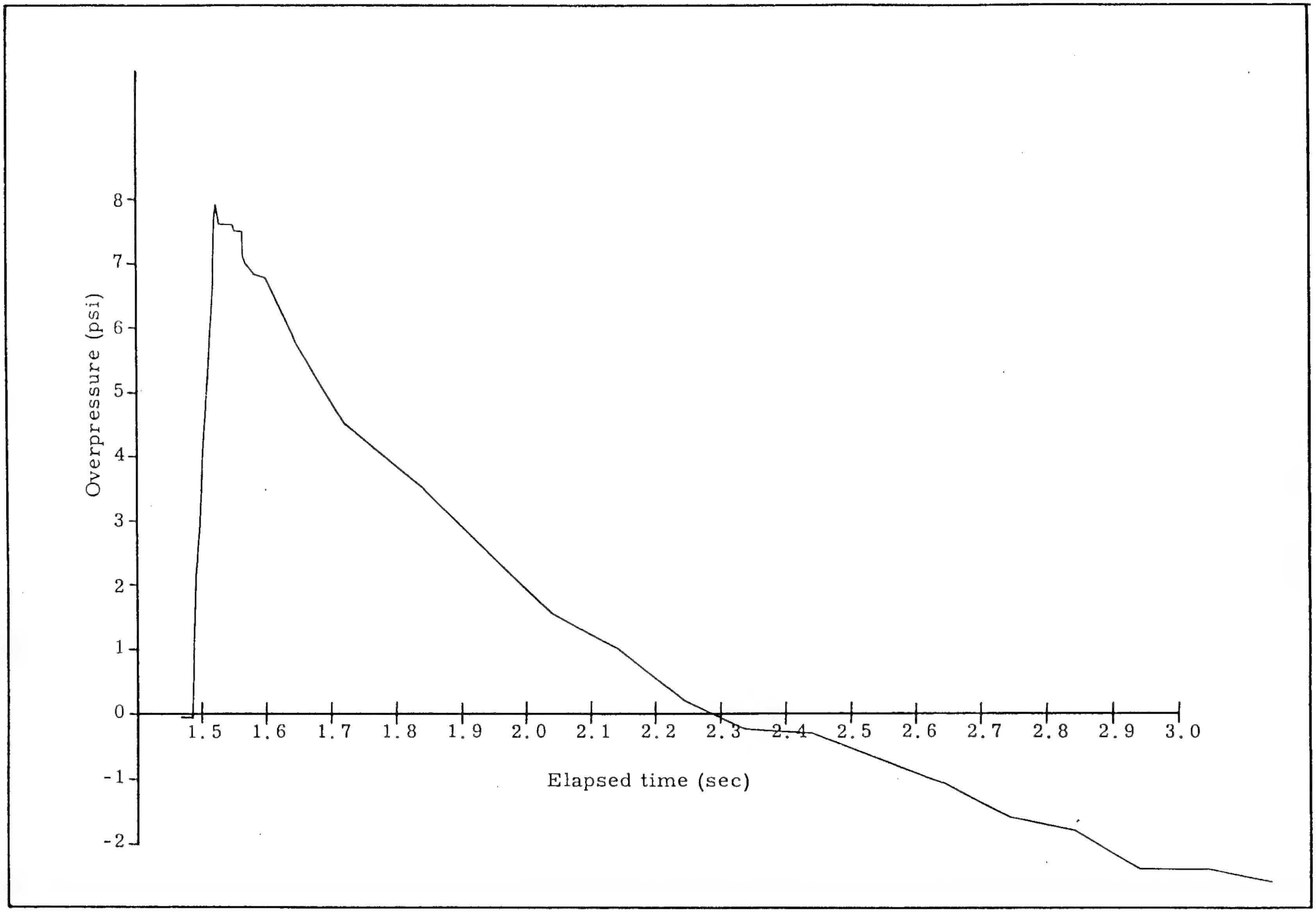


Fig. 73. -- Shot Easy (DS) (ground baffle) (distance from ground zero: 2,910 ft)

[redacted]

[redacted]

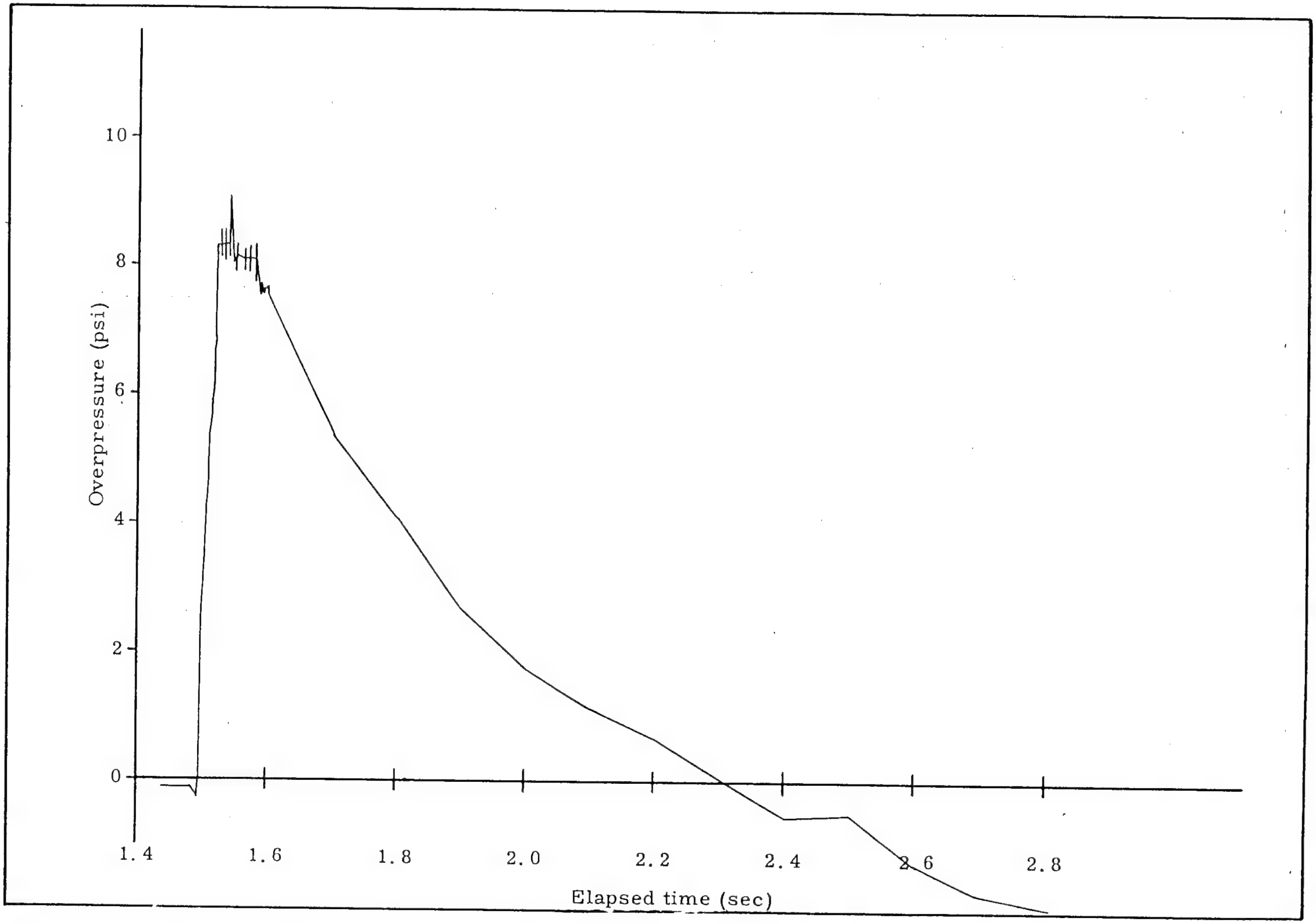


Fig. 74. -- Shot Easy (DPO) (ground baffle) (distance from ground zero: 2,910 ft)

[redacted]

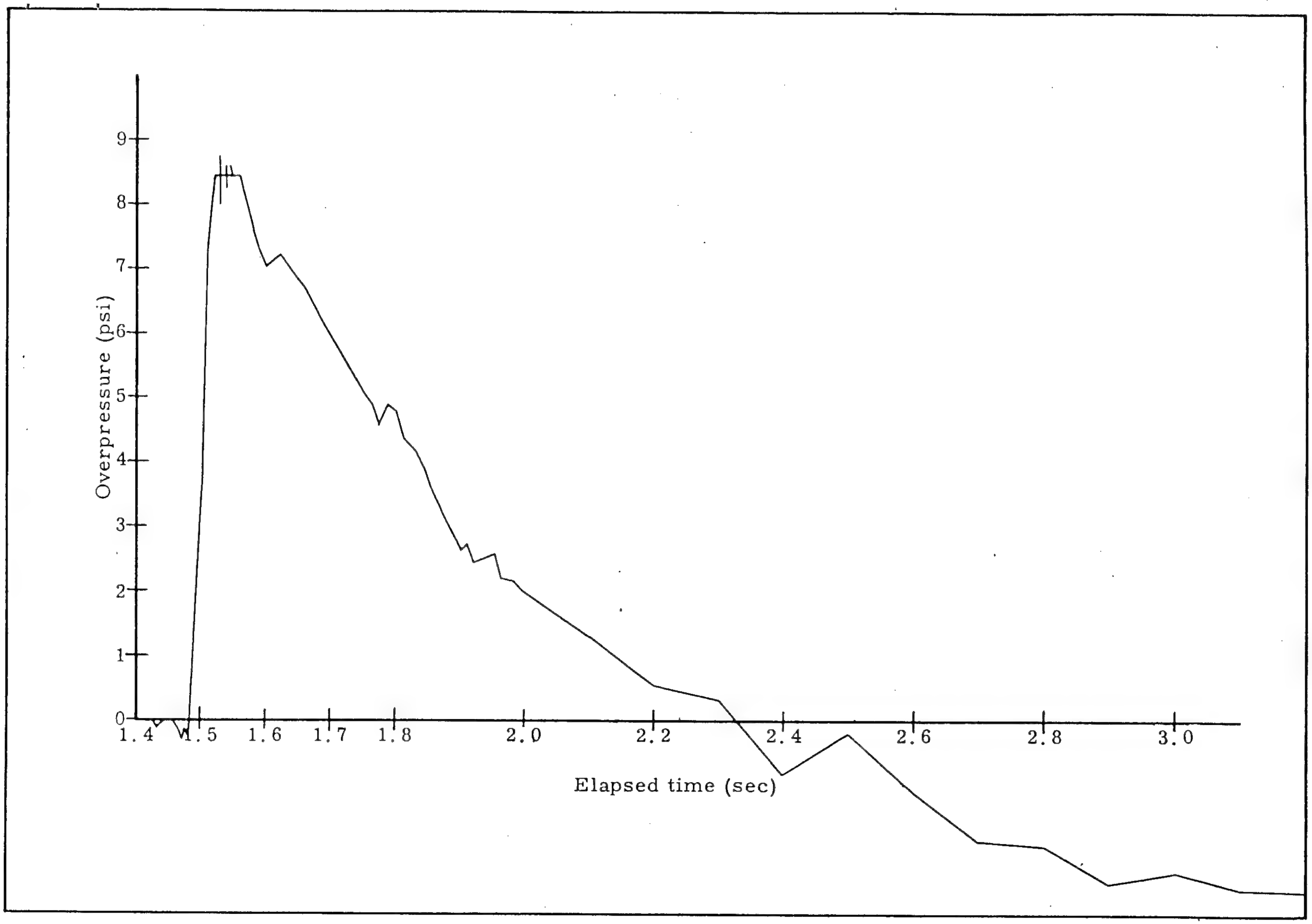


Fig. 75. -- Shot Easy (DP5) (gauge 5 ft above ground) (distance from ground zero: 2,910 ft)

[redacted]

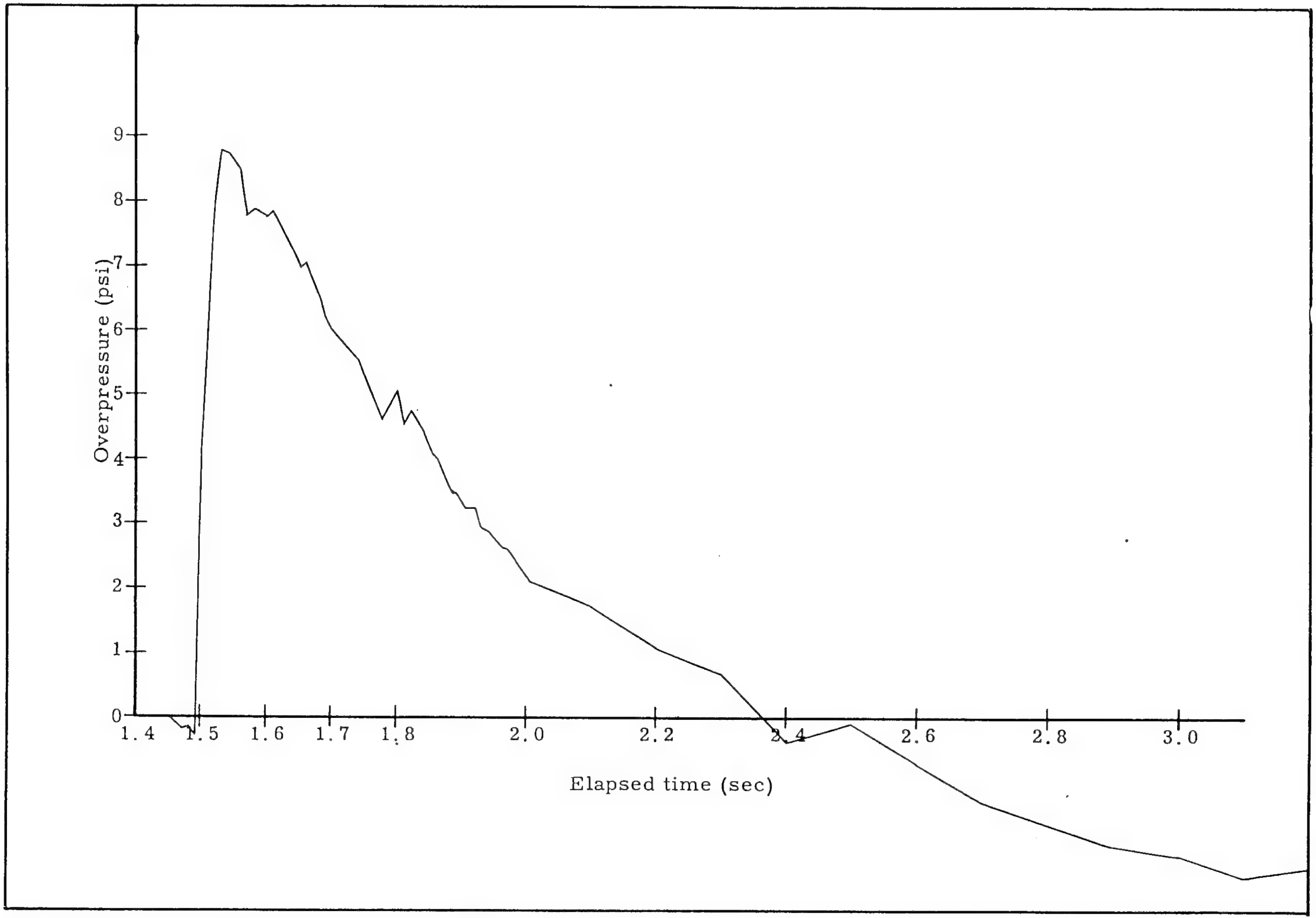


Fig. 76. -- Shot Easy (DP10) (gauge 10 ft above ground) (distance from ground zero: 2,910 ft)

[redacted]

[redacted]

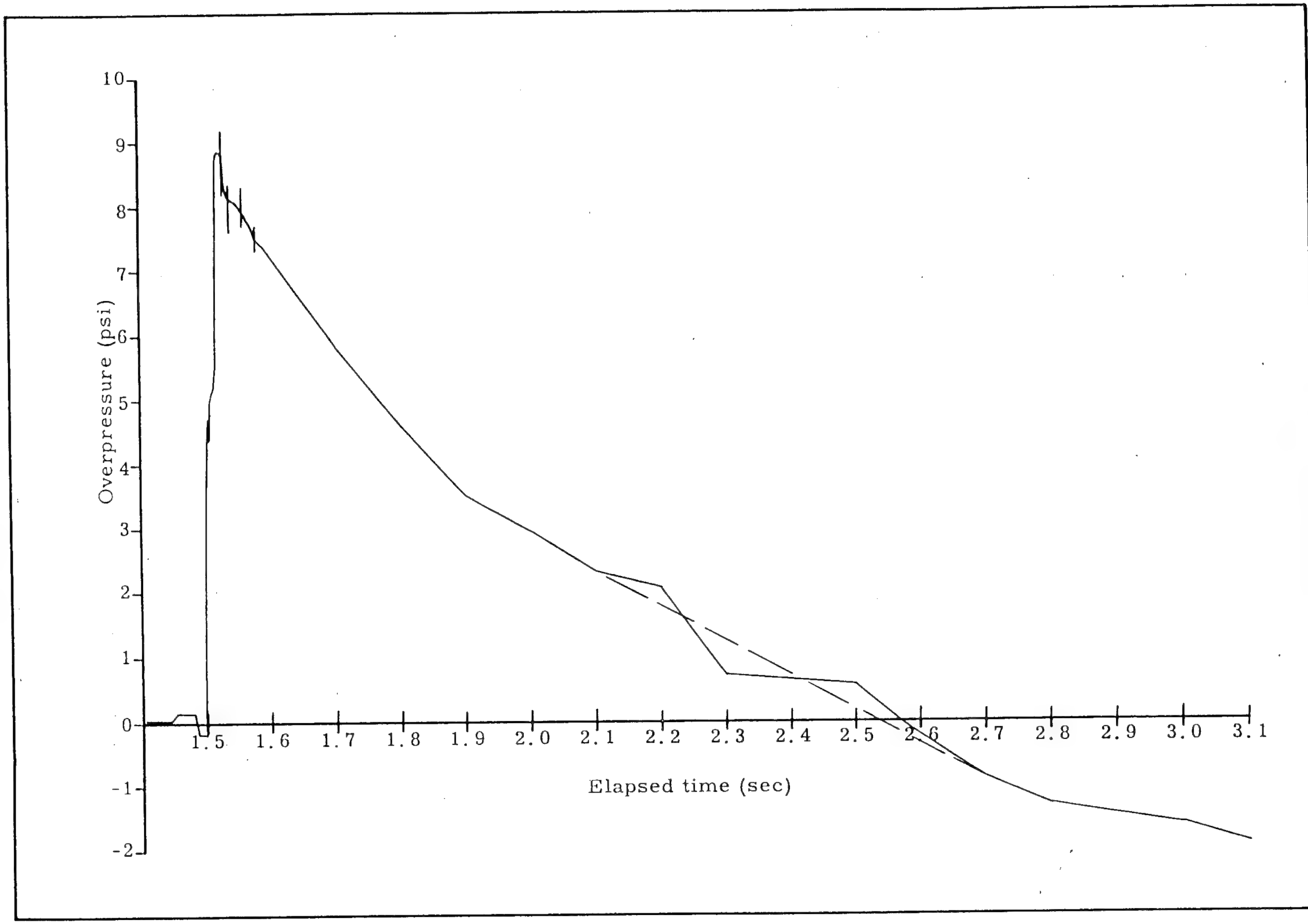


Fig. 77. -- Shot Easy (DP25) (gauge 25 ft above ground) (distance from ground zero: 2, 910 ft)

[redacted]

[redacted]

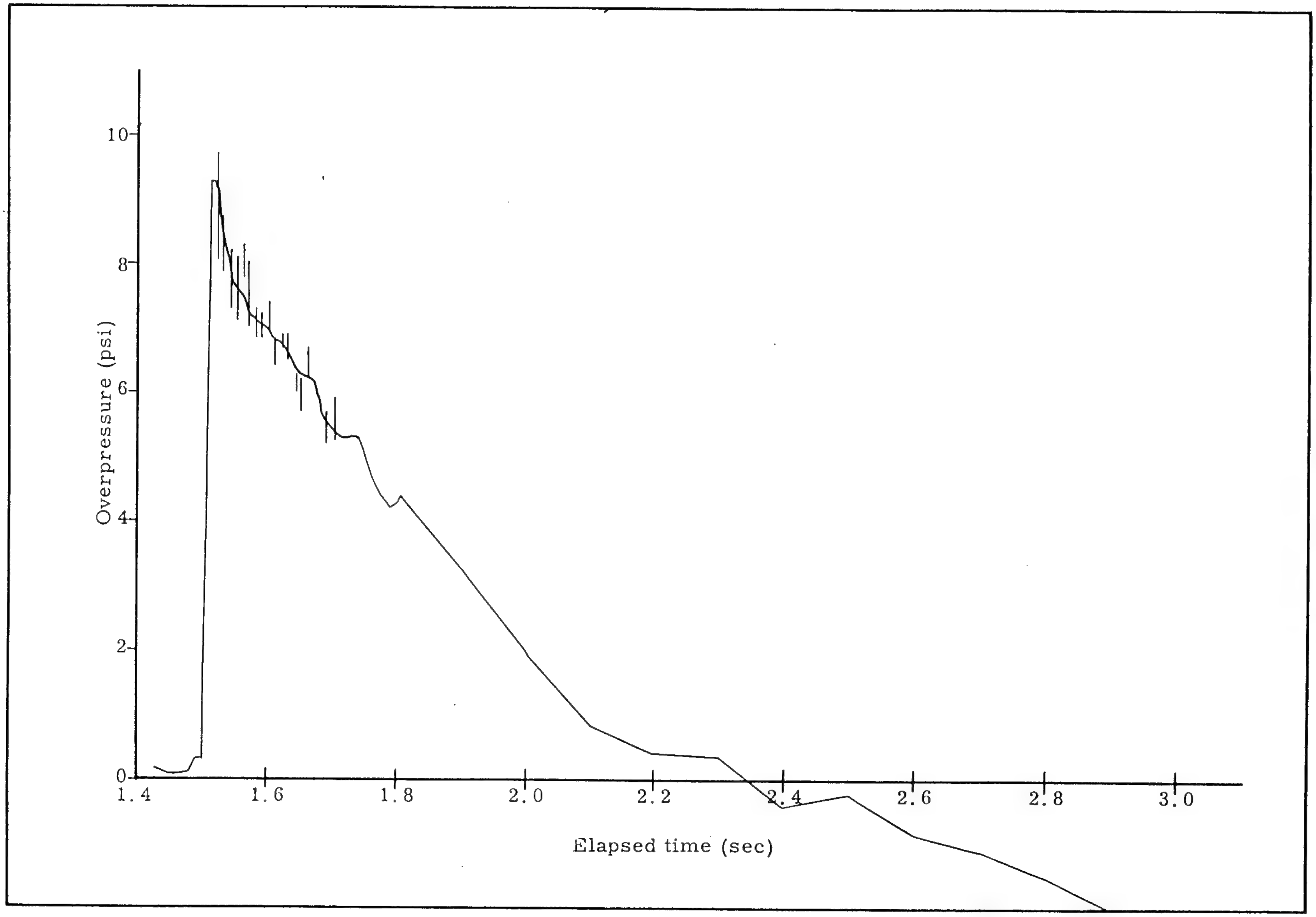


Fig. 78. -- Shot Easy (DP50) (gauge 50 ft above ground) (distance from ground zero: 2,910 ft)

[redacted]

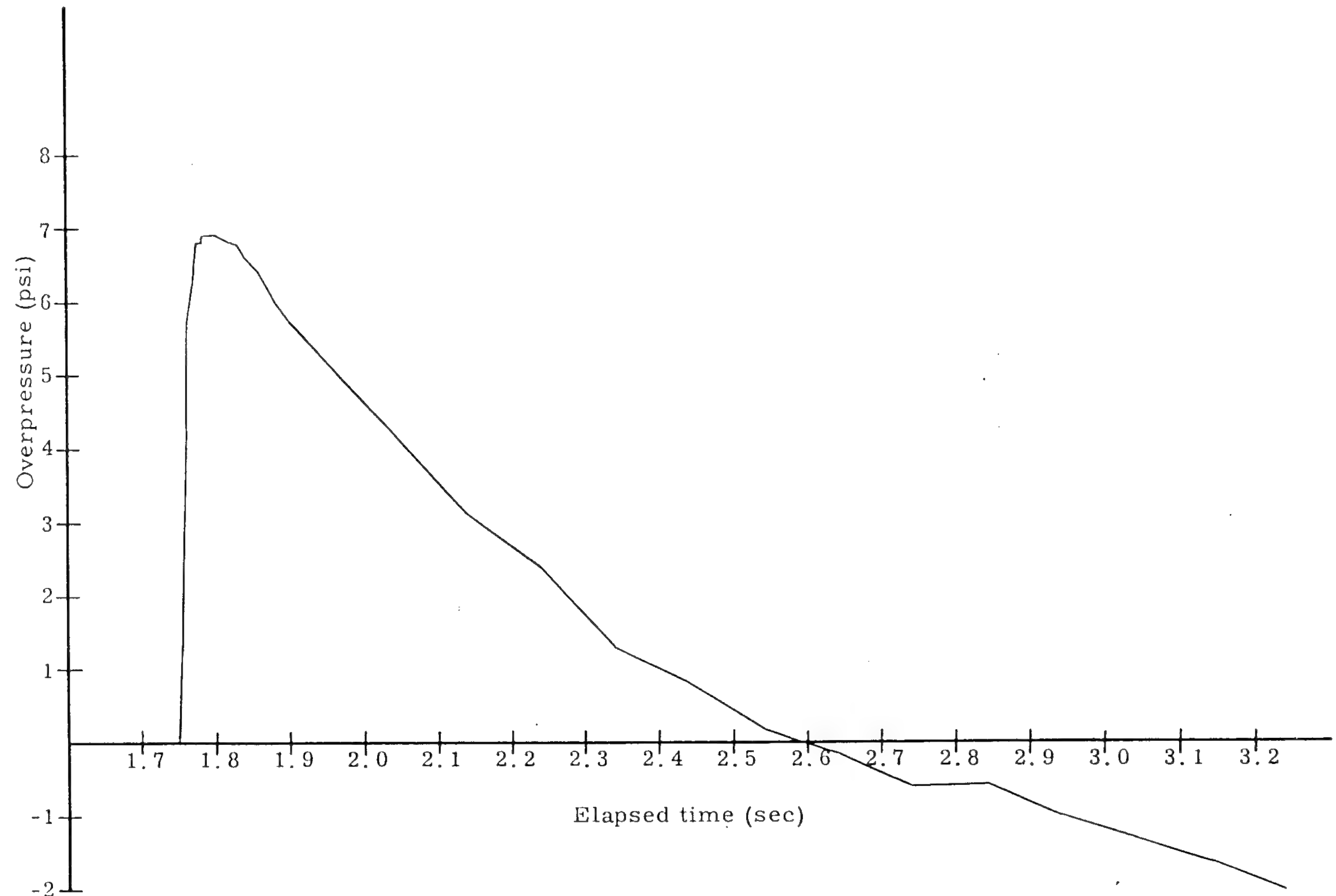


Fig. 79. -- Shot Easy (ES) (ground baffle) (distance from ground zero: 3, 270 ft)

[redacted]

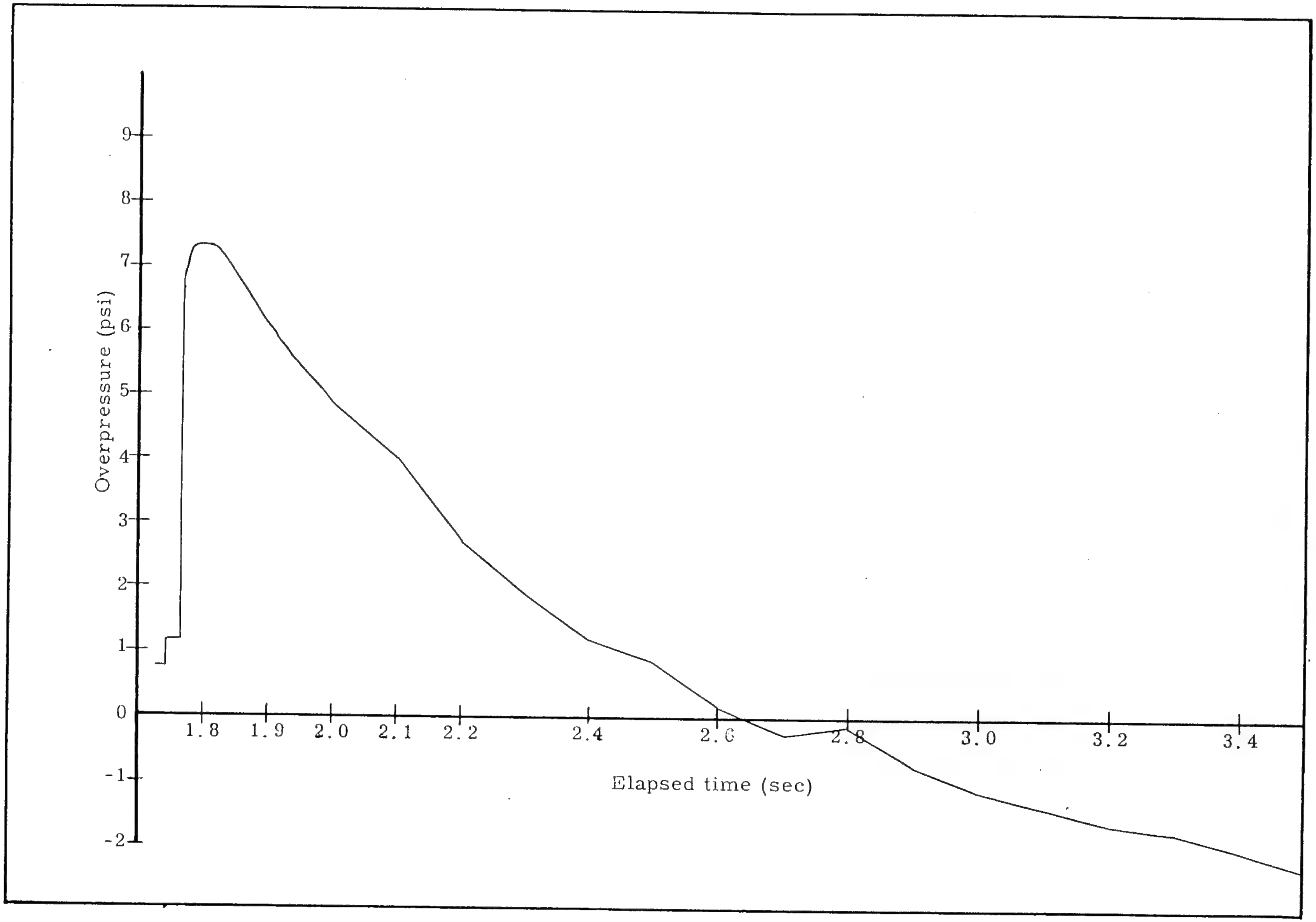


Fig. 80 -- Shot Easy (E15L) (gauge 15 ft above ground) (distance from ground zero: 3,270 ft)

[redacted]

[redacted]

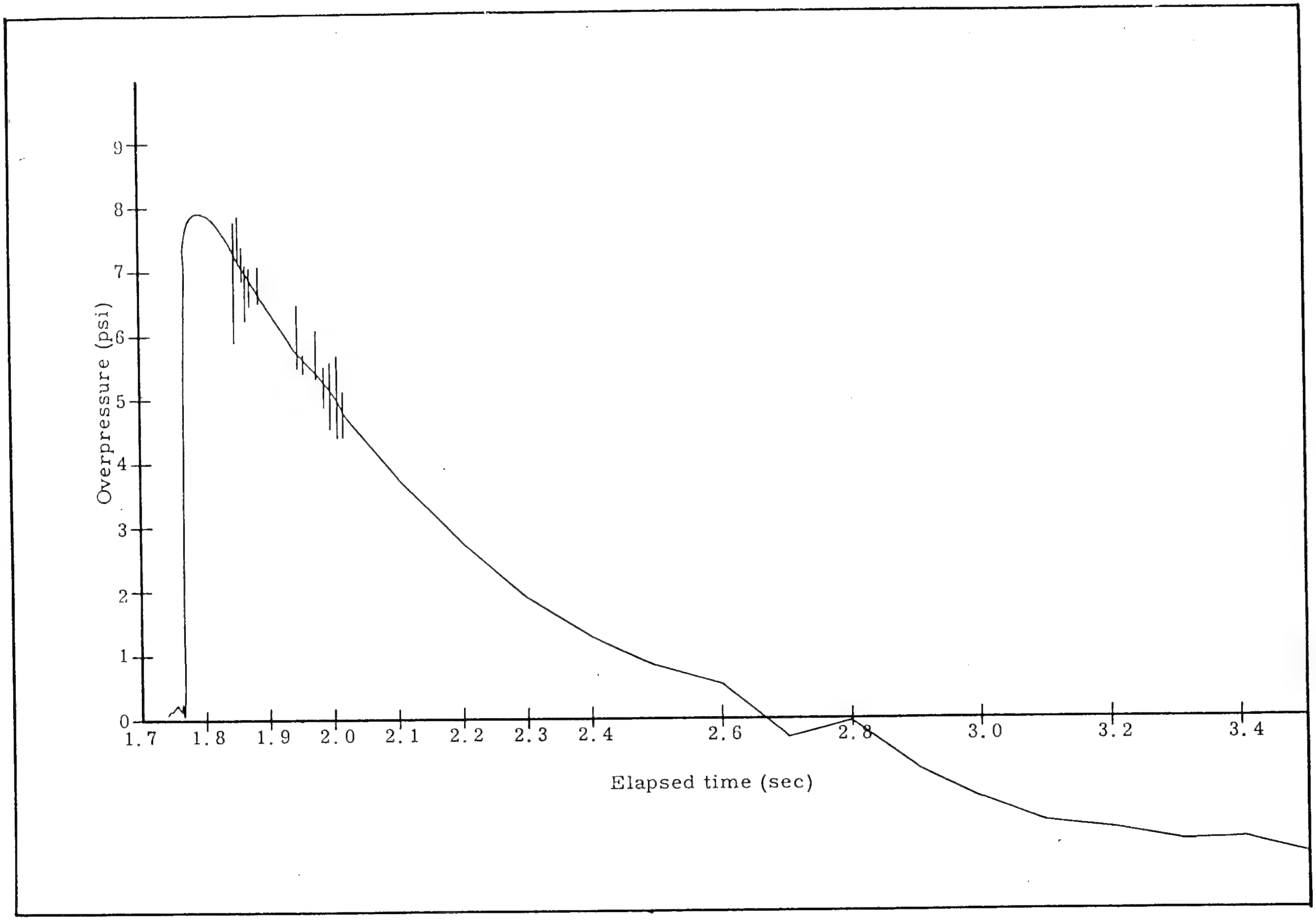


Fig. 81. -- Shot Easy (E15R) (gauge 15 ft above ground) (distance from ground zero: 3,270 ft)

[redacted]

[redacted]

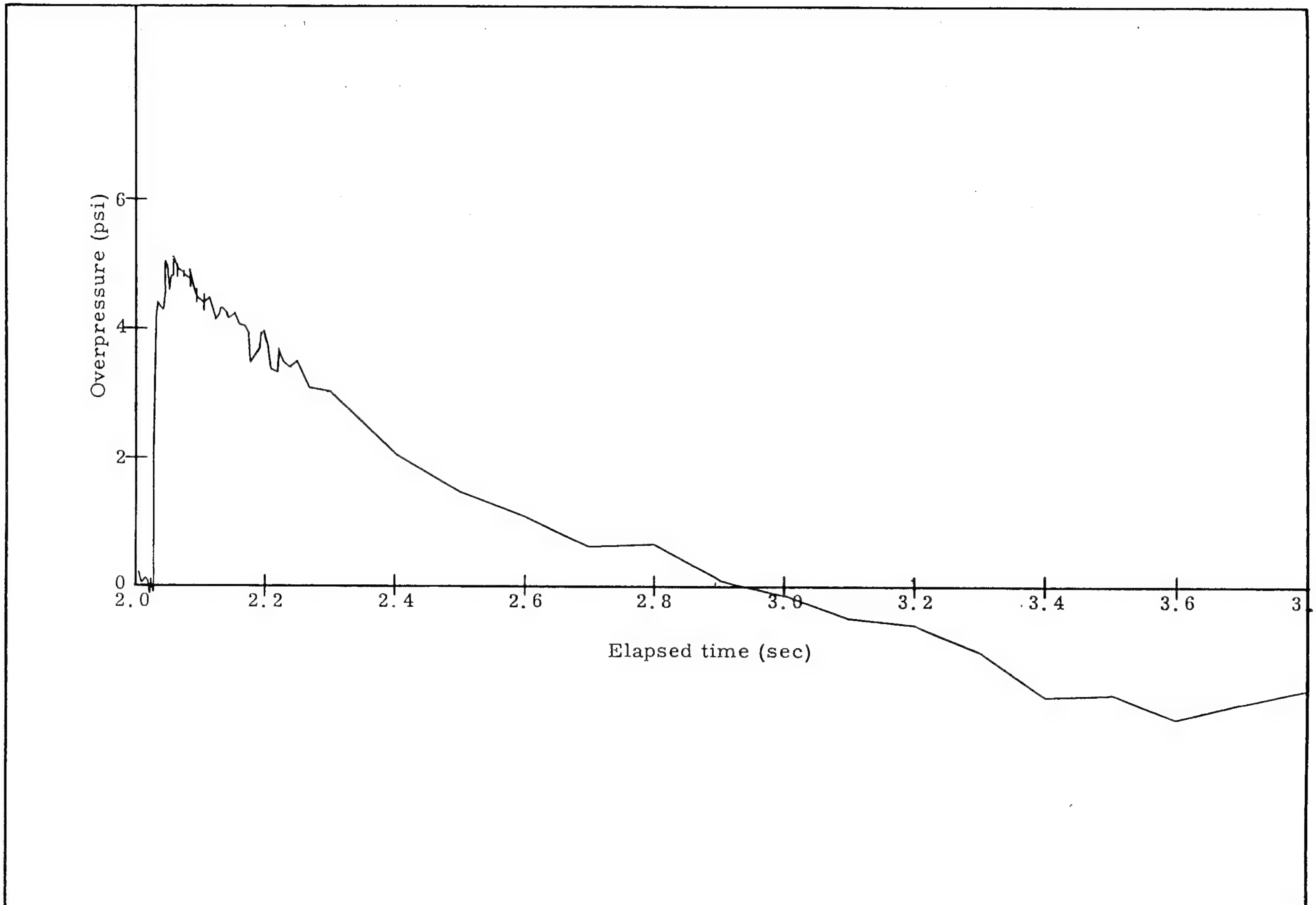


Fig. 82. -- Shot Easy (FS) (ground baffle) (distance from ground zero: 3,630 ft)

[redacted]

[redacted]

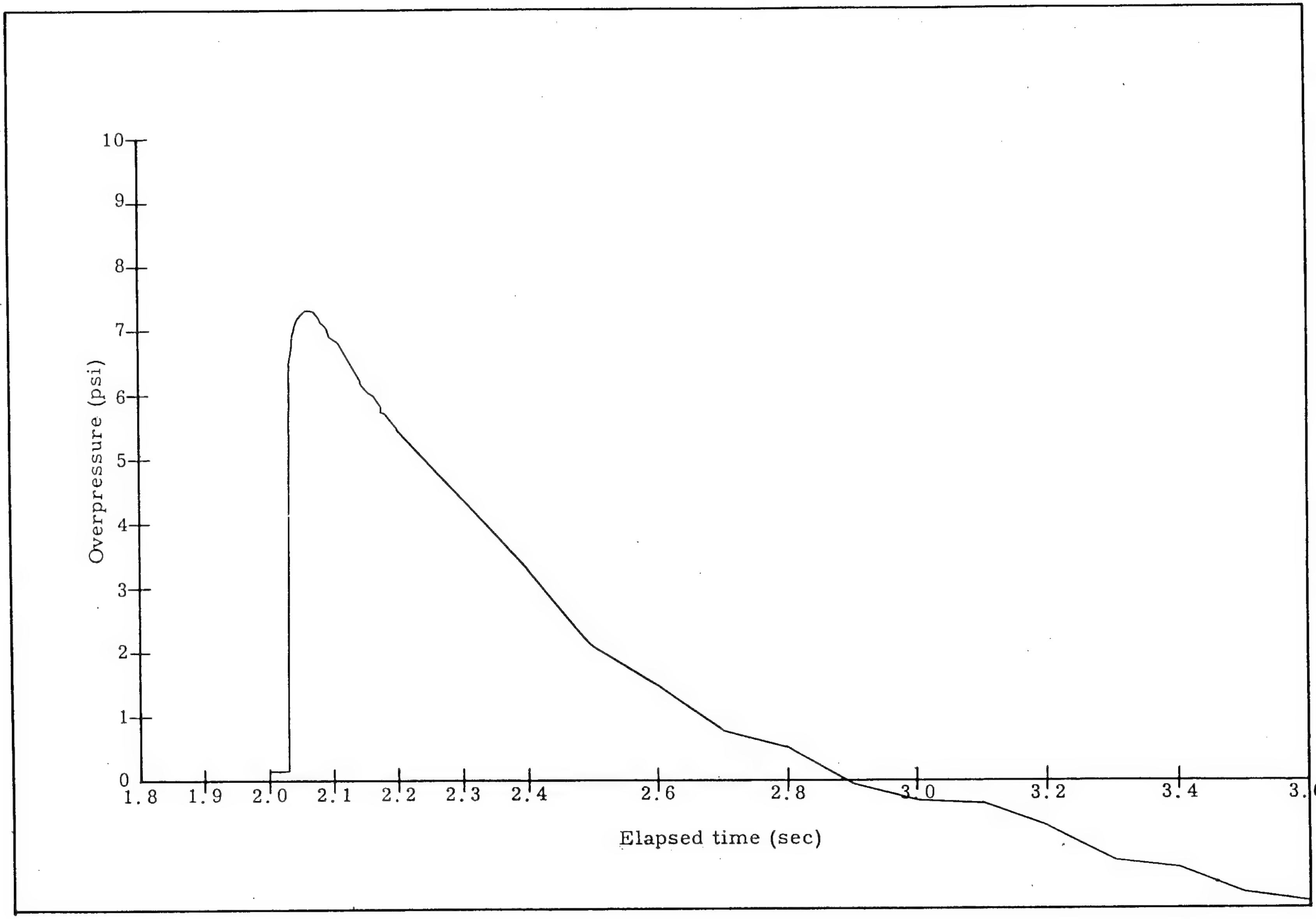


Fig. 83. -- Shot Easy (F15R) (gauge 15 ft above ground) (distance from ground zero: 3,630 ft)

[redacted]

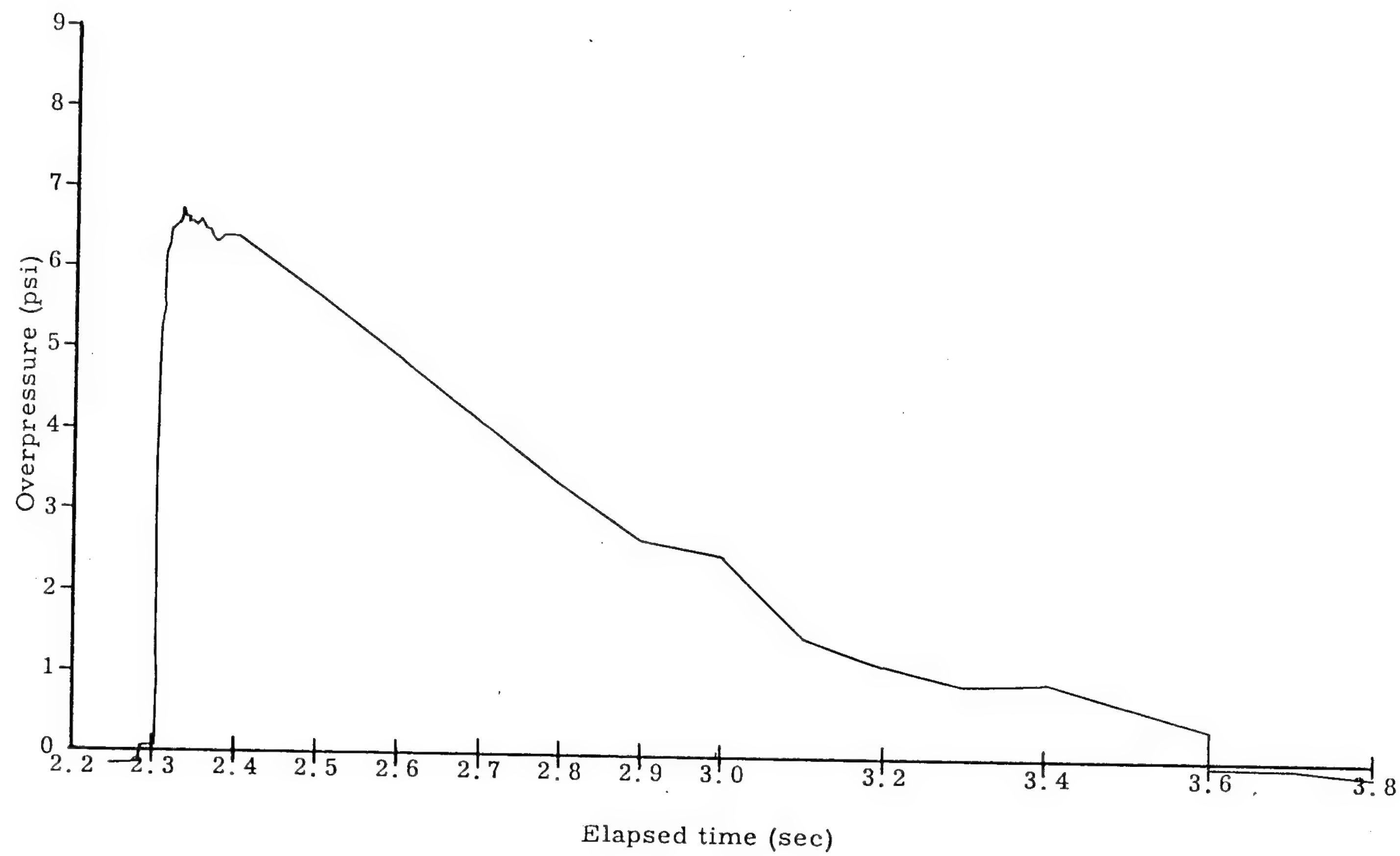


Fig. 84. -- Shot Easy (GS) (ground baffle) (distance from ground zero: 3,995 ft)

[redacted]

[redacted]

[redacted]

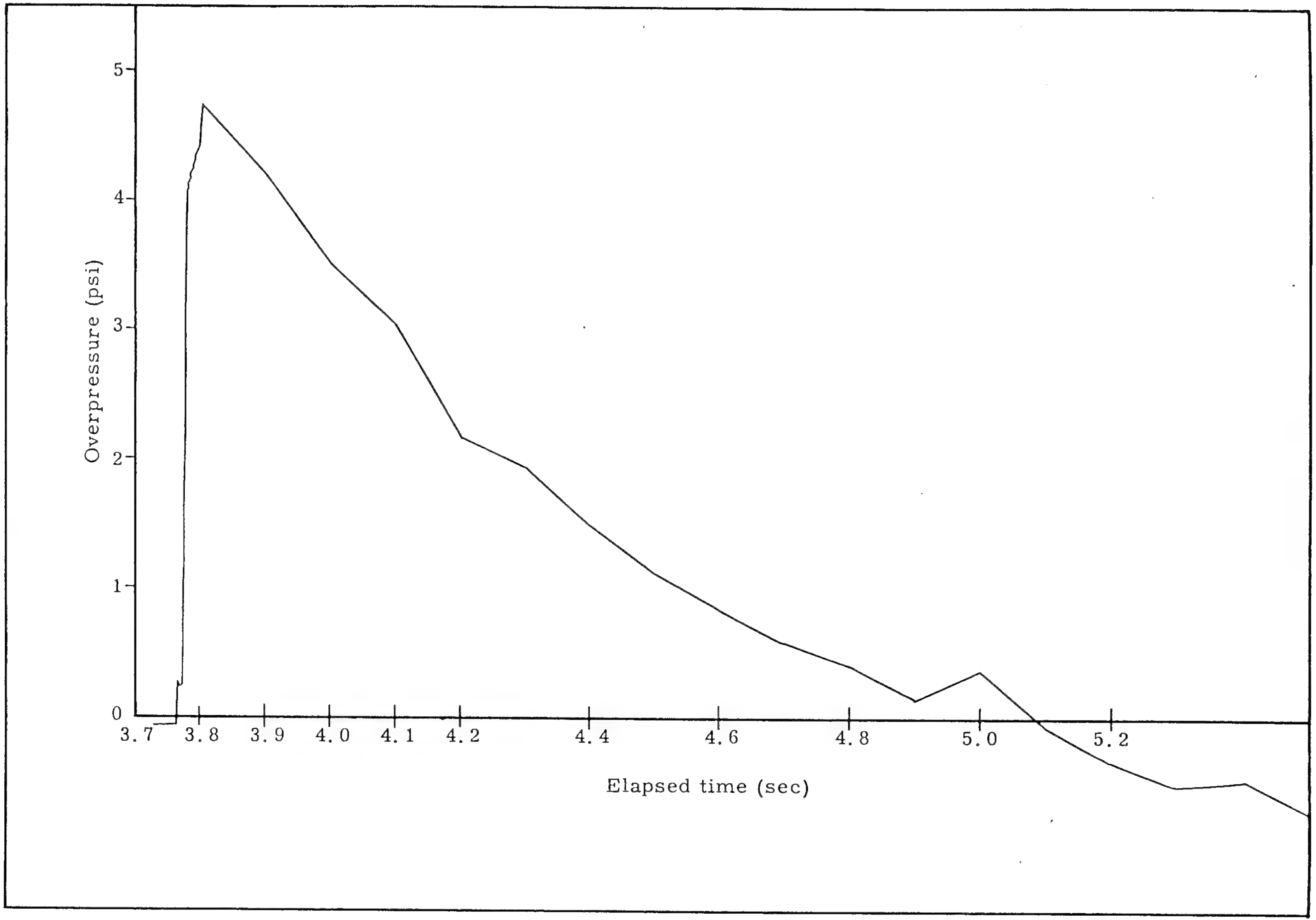


Fig. 85. -- Shot Easy (IS) (ground baffle) (distance from ground zero: 5,860 ft)

[redacted]

[redacted]

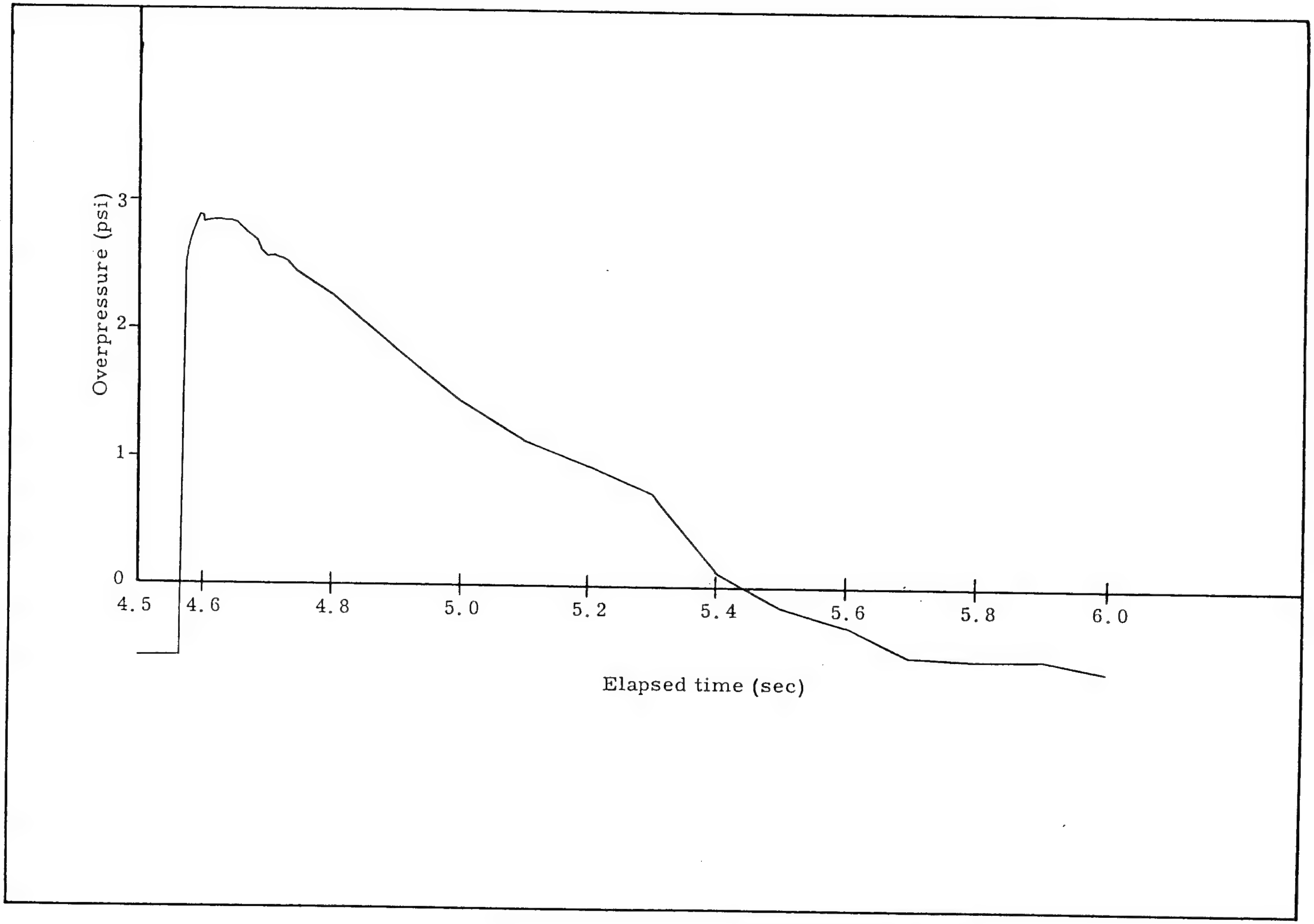


Fig. 86. -- Shot Easy (JS) (ground baffle) (distance from ground zero: 6,250 ft)

[redacted]

Appendix B to:
Operation Buster
Some Measurements of Overpressure-Time vs Distance
for Airburst Bombs

The recording system consisted mainly of three commercially available items:

1. Wiancko pressure gauges manufactured by the Wiancko Engineering Company of Pasadena, California. A description of these gauges can be found in Greenhouse Report Annex 3.4, Part 1.[11]

2. Carrier-Amplifier System D manufactured by the Consolidated Engineering Corporation. This system employs a 3 kc/sec carrier, permitting flat response from zero to 500 cps. The rise time (including the galvanometer, Consolidated type 7-223) when a step transient is applied through the system is slightly faster than one msec.

3. Type 5-114 18-channel recording oscillographs manufactured by the Consolidated Engineering Corporation.

All the equipment was operated on 110 volts a-c except one of the recording oscillographs, which was battery-powered.

[redacted]

LIST OF REFERENCES

1. Porzel, F. B. and Reines, F., Height of Burst for Atomic Bombs, Los Alamos report LA-743R, August 1949

2. Pelsor, G. T., Overpressure Expected from an A-Bomb Burst Over a Rigid Plane, Sandia Corporation report SC-1516(TR), July 1950

3. The Capabilities of Atomic Weapons, Armed Forces Special Weapons Project report AFSWP-Q-21, July 1951

4. An Analysis of the Strategic Uses of the Airburst Bomb with Special Reference to the Fuzing Problem, Sandia Corporation report SC-1827(TR), May 1951

5. Harding, J. M., Fixed Distance Blast Pressure Variation with Small Altitude, Buster-Jangle report WT-305, April 3, 1952

6. Merritt, M. L., Some Measurements of Terrain Effects on Blast Waves, Buster-Jangle report WT-301, February 12, 1952

7. White, D. R., An Experimental Survey of the Mach Reflection of Shock Waves, Princeton University Technical report II-10, August 21, 1951

8. Effects of Atomic Weapons, prepared by the Los Alamos Scientific Laboratory, U. S. Government Printing Office, 1950, Fig. 3.40a

9. Operation Greenhouse, Report Number 28, Annex 1.6 Part VI -- Pressure Versus Time in Mach Region (to be published)

10. Memorandum, Porzel, F. B., Los Alamos Scientific Laboratory, and Pelsor, G. T., Sandia Corporation, to Bradbury, N. E., Los Alamos Scientific Laboratory, The Implication of the Buster-Jangle Blast Measurements, January 23, 1952

11. Northrop, P. A., Instrumentation of Structures Program, Scientific Director's report on Operation Greenhouse, WT-1(Annex 3.4, Part 1) January 1951

[redacted]

[redacted]

INITIAL DISTRIBUTION

ATOMIC ENERGY COMMISSION

1-3/300A	Atomic Energy Commission, Washington, Attn: DMA
4-23/300A	Los Alamos Scientific Laboratory, Report Library
24-45/300A	Sandia Corporation
46/300A	Weapon Test Reports Group, TIS, USAEC, Washington
264-300/300A	Technical Information Service, Oak Ridge (surplus)

DEPARTMENT OF DEFENSE
(thru TIS, Oak Ridge)

47/300A	Chairman, Research and Development Board
48/300A	Director, Weapons System Evaluations Group, Office of the Secretary of Defense
49/300A	Executive Director, Committee on Atomic Energy, Research and Development Board (Beckler)
50/300A	Executive Director, Committee on Medical Sciences, Research and Development Board

AFSWP ACTIVITIES
(direct)

51-59/300A	Chief, Armed Forces Special Weapons Project, Washington
60-62/300A	Commanding General, Field Command, Armed Forces Special Weapons Project, Albuquerque
63-65/300A	Commanding Officer, Test Command, Armed Forces Special Weapons Project, Albuquerque

ARMY ACTIVITIES
(thru TIS, Oak Ridge)

66/300A	Assistant Chief of Staff, G-1
67/300A	Assistant Chief of Staff, G-2
68-71/300A	Assistant Chief of Staff, G-3
72-76/300A	Assistant Chief of Staff, G-4
77-79/300A	Chief of Ordnance
80-83/300A	Chief Chemical Officer
84-86/300A	Chief of Engineers
87-91/300A	Quartermaster General
92-93/300A	Chief of Transportation
94-96/300A	Chief Signal Officer
97-100/300A	Surgeon General

[redacted]

[redacted]

INITIAL DISTRIBUTION (Cont)

UNCLASSIFIED

ARMY ACTIVITIES (Cont)
(thru TIS, Oak Ridge)

101-103/300A	Provost Marshal General
104-107/300A	Chief, Army Field Forces
108/300A	President, Army Field Forces Board No. 1, Fort Bragg
109/300A	President, Army Field Forces Board No. 2, Fort Knox
110/300A	President, Army Field Forces Board No. 3, Fort Benning
111/300A	President, Army Field Forces Board No. 4, Fort Bliss
112-113/300A	Commandant, Infantry School, Fort Benning
114-115/300A	Commandant, Armored School, Fort Knox
116-117/300A	President, Artillery School Board, Fort Sill
118-119/300A	Commandant, AA&GM Branch, Artillery School, Fort Bliss
120-121/300A	Commandant, Army War College
122-123/300A	Commandant, Command and General Staff College, Fort Leavenworth
124/300A	Commandant, Army General School, Fort Riley
125-126/300A	Commanding General, First Army, Governor's Island
127-128/300A	Commanding General, Second Army, Fort George G. Meade
129-130/300A	Commanding General, Third Army, Fort McPherson
131-132/300A	Commanding General, Fourth Army, Fort Sam Houston
133-134/300A	Commanding General, Fifth Army, Chicago
135-136/300A	Commanding General, Sixth Army, Presidio of San Francisco
137-138/300A	Commander-in-Chief, European Command
139-140/300A	Commander-in-Chief, Far East
141-142/300A	Commanding General, U. S. Army, Pacific
143-144/300A	Commanding General, U. S. Army, Caribbean
145-146/300A	Commanding General, U. S. Army, Alaska
147-148/300A	Operations Research Office (Johns Hopkins University)
149-150/300A	Commanding Officer, Ballistic Research Laboratories
151-152/300A	Commanding Officer, Engineer Research and Development Laboratory
153-154/300A	Commanding Officer, Signal Corps Engineering Laboratory, Fort Monmouth
155-156/300A	Commanding Officer, Evans Signal Laboratory
157-158/300A	Commanding General, Army Chemical Center, Chemical and Radiological Laboratory

NAVY ACTIVITIES
(thru TIS, Oak Ridge)

159-160/300A	Chief of Naval Operations, Op-36
161-164/300A	Chief, Bureau of Ships
165/300A	Chief, Bureau of Ordnance
166-167/300A	Chief, Bureau of Medicine and Surgery
168-169/300A	Chief, Bureau of Aeronautics
170-171/300A	Chief, Bureau of Supplies and Accounts
172-174/300A	Chief, Bureau of Yards and Docks
175/300A	Chief of Naval Personnel
176-178/300A	Commandant of the Marine Corps
179/300A	Commander-in-Chief, U. S. Pacific Fleet

LASSIFIED

[redacted]

[redacted]

UNCLASSIFIED

INITIAL DISTRIBUTION (Cont)

NAVY ACTIVITIES (Cont)
(thru TIS, Oak Ridge)

180/300A	Commander-in-Chief, U. S. Atlantic Fleet
181/300A	President, U. S. Naval War College, Newport
182-183/300A	Commandant, Marine Corps Schools, Quantico
184-185/300A	Chief of Naval Research
186/300A	Commander, U. S. Naval Ordnance Laboratory
187/300A	Commander, U. S. Naval Ordnance Laboratory (Aliex)
188/300A	Director, U. S. Naval Research Laboratory
189/300A	Commanding Officer and Director, U. S. Naval Electronics Laboratory
190-193/300A	Commanding Officer, U. S. Naval Radiological Defense Laboratory
194/300A	Commanding Officer and Director, David W. Taylor Model Basin
195/300A	Commander, Naval Material Laboratory
196-197/300A	Officer-in-Charge, U. S. Naval Civil Engineering Research and Evaluation Laboratory
198/300A	Commander, U. S. Naval Ordnance Test Station, Inyokern
199/300A	Commanding Officer, U. S. Naval Medical Research Institute

AIR FORCE ACTIVITIES
(thru TIS, Oak Ridge)

200-201/300A	Assistant for Atomic Energy
202-203/300A	Director of Operations, Operations Analysis Division
204/300A	Director of Plans (AFORD-Pl)
205/300A	Director of Requirements
206-207/300A	Director of Research and Development
208-209/300A	Director of Intelligence (Phys. Vul. Branch, Air Targets Division)
210/300A	Director of Installations
211/300A	Assistant for Development Planning
212/300A	Assistant for Materiel Program Control
213/300A	Surgeon General
214-216/300A	Commanding General, Strategic Air Command, Offutt Air Force Base
217-226/300A	Commanding General, Air Research and Development Command
227-228/300A	Commanding General, Air Materiel Command, Wright-Patterson Air Force Base
229-230/300A	Commanding General, Air Materiel Command, Wright-Patterson Air Force Base, Air Installations Division
231-233/300A	Commanding General, Tactical Air Command, Langley Air Force Base
234-236/300A	Commanding General, Air Defense Command, Ent Air Force Base
237-238/300A	Commanding General, Air Proving Ground, Eglin Air Force Base
239-241/300A	Commanding General, Air Training Command, Scott Air Force Base

UNCLASSIFIED

[redacted]

[redacted]

UNCLASSIFIED

INITIAL DISTRIBUTION (Cont)

AIR FORCE ACTIVITIES (Cont)
(thru TIS, Oak Ridge)

242-244/300A	Commanding General, Air University, Maxwell Air Force Base
245-247/300A	Commanding General, Special Weapons Center, Kirtland Air Force Base
248/300A	Commanding General, 1009th Special Weapons Squadron
249-252/300A	Commanding General, Wright Air Development Center, Wright-Patterson Air Force Base
253-254/300A	Commanding General, U. S. Air Forces in Europe
255-256/300A	Commanding General, U. S. Air Forces, Far East
257-258/300A	Commanding General, Air Forces Cambridge Research Center
259/300A	Commanding General, Air Force Missile Center, Patrick Air Force Base
260/300A	Commandant, School of Aviation Medicine, Randolph Air Force Base
261-262/300A	RAND Corporation
263/300A	Assistant to the Special Assistant Chief of Staff (Griggs)

UNCLASSIFIED

[redacted]